22

# PRELIMINARY DESIGN REPORT

ON

# POWERHOUSE
# PASSAMAQUODDY TIDAL POWER PROJECT

FOR

## CORPS OF ENGINEERS, U. S. ARMY
### NEW ENGLAND DIVISION, BOSTON, MASSACHUSETTS

STONE & WEBSTER
ENGINEERING CORPORATION


PASSAMAQUODDY
PASSAMAQUODDY POWERHOUSE
INTERNATIONAL TIDAL POWER PROJECT
STONE & WEBSTER ENGINEERING CORPORATION

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Stone & Webster Engineering Corporation

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June 30, 1958

Division Engineer,
Corps of Engineers, U. S. Army,
Office of the Division Engineer,
New England Division,
150 Causeway Street,
Boston 14, Massachusetts.

Dear Sir:

In accordance with Contract No. DA-19-016-CIV ENG-58-9 dated August 5, 1957, we have prepared a preliminary design of a powerhouse for the proposed Passamaquoddy Tidal Power Project and estimated the cost of constructing such a plant.

The design has been based on an installation of 30 - 10,000 kw units. An outdoor-type of powerhouse has been adopted as a result of a detailed comparison of outdoor, semioutdoor and indoor types of powerhouses and discussions with you. Units would be grouped electrically, two groups of seven and two of eight. Four 90,000 kva transformers would handle the entire plant output, with each group feeding into a transformer. Each group would have its own control center, and control of the entire plant would be from a supervisory board at the center of the powerhouse. Transmission to the switchyard would be by means of high pressure pipe type cable. Service bays would be located at each end of the powerhouse. Two powerhouse gantry cranes would be provided, these would be self-propelled and would have rolling doors to enclose the areas under the cranes for protection against inclement weather.

We estimate that the powerhouse would cost $130,000,000, assuming labor, material and equipment costs as of January, 1958. This includes the cost of generators and turbines which would be purchased by the Corps of Engineers at a cost, estimated by you, of $1,000,000 each for generators, including exciters and erection, and $1,000,000 each for turbines, including governors but not erection. This estimate includes the entire contractor's costs, including overhead and profit. The estimate does not include an item for normal contingencies nor costs for fresh water, excavation, backfill, cofferdams and unwatering, as these items will be included in your estimates covering other elements of the project. Also, the estimate does not include the costs of design and field engineering nor the cost of construction supervision.

Details of the design and estimate are contained in the following pages of this report.

Yours very truly,

F. W. Argue

F. W. Argue,
Engineering Manager.

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## APPENDICES

## PURPOSE AND SCOPE

The proposed Passamaquoddy Tidal Power Project would utilize the tides in Passamaquoddy Bay for the generation of hydroelectric power. This bay, between the State of Maine and the Province of New Brunswick, is an arm of the Bay of Fundy which has the greatest tidal ranges in the world, amounting to more than 50 ft. In Passamaquoddy Bay itself, tides average 18 ft.

The study of the entire project, under the direction of the Corps of Engineers, U.S. Army, is being made to determine whether construction of the project would be economically feasible.

This report presents an estimate of the cost of constructing the power plant. As a basis for this estimate, preliminary drawings have been prepared and are included in the report. Descriptions of the various systems and major items of equipment are also included to complement the drawings and give a better understanding of the proposed design. Where important alternatives have been considered, for example, the type of powerhouse to be adopted, brief resumés of the comparisons are included, as well as the reasons for the selection of the design chosen.

## POWERHOUSE ARRANGEMENT

### GENERAL

The Corps of Engineers has set the location of the powerhouse and the size and number of generating units. The powerhouse would be located on the southwest side of Moose Island in Carrying Place Cove about one-half mile northwest of the airport serving the City of Eastport, Maine. The powerhouse would contain 30 units, each rated at 10,000 kw, so that total plant capacity would be rated at 300,000 kw.

By means of a system of dams and tidal gates, the Corps plans to maintain a positive head on the powerhouse at all times. Passamaquoddy Bay would draw water from the Bay of Fundy and would serve as the headwater pool with water level controlled between El. 13.5' maximum and El. 3.0' minimum (mean sea level). Cobscook Bay would serve as the tail water pool and be controlled between El. 0.0' maximum and El. -13.0' minimum. In this way, flow would always be from the Bay of Fundy to Passamaquoddy Bay through the powerhouse to Cobscook Bay and finally back to the Bay of Fundy. On the basis of studies by the Corps of Engineers, head on the powerhouse would vary between 21 ft maximum and 6 ft minimum.

The Corps of Engineers has also set the size of the turbine water passageways, as described in its Interim Report, "Turbine and Generator Studies" dated September, 1957. Each unit bay would contain three passageways, each 17 ft-4 in. wide, to be separated by two interior piers, 6 ft-6 in. wide. A preliminary structural analysis of the end piers indicates that these also could be made 6 ft-6 in. wide. Consequently, unit spacing would be 78 ft-0 in., and the 30 units would require a length of 2,340 ft.

For general views of the powerhouse in plan and section, reference is made to Plate I, General Arrangement, Plate II, Typical Cross Section, and Plate III, Plan - Operating Floor.

Similarly, the size of the water passageways has played a key role in establishing the main elevations of the plant. The Corps has set the ceiling of the concrete scroll case at El. 7.0', as is shown on Plate II, Typical Cross Section. With a scroll case roof thickness of 5 ft, the lowest floor level in the powerhouse would be at El. 12.0'. The next level has been established at El. 27.0' by allowing 12 ft of headroom and a 3 ft structural slab roof; headroom under beams would be 10 ft. The roof deck, therefore, would be well above maximum high water level at El. 13.5' even considering the effects of storm waves that might reach, upon striking a vertical face, an estimated 7 to 8 ft above the still pool water level. Consequently, structures above El. 12.0' would be essentially those necessary to house and support powerhouse equipment.

Because vertical space requirements between the generator and turbine have required the generators to be placed on the El. 27.0' level, ample space would be available on the El. 12.0' level for operating and auxiliary electrical and mechanical equipment. With the greater space on the upstream side of the units, this space has been allocated for electrical equipment, while space on the downstream side has been allocated for mechanical equipment and piping.

With such an arrangement, the main transformers have been placed on the intake deck at El. 27.0'. This is an ideal location in terms of powerhouse costs, proximity to generators and electrical control equipment and transmission to the switchyard, which the Corps of Engineers has located on the upstream side of the powerhouse.

Access to the plant, both highway and railroad, would be at the east end of the powerhouse. The Corps of Engineers has stated that topography at the east end is such that the railroad would approach the plant along the longitudinal axis of the powerhouse.

## TYPE OF POWERHOUSE

Careful consideration has been given to the type of powerhouse to be adopted. Three layouts were prepared; one for the indoor type, one for the semioutdoor type and one for the outdoor type, all based on similar equipment arrangements for thirty 10,000 kw units.

In all three types of powerhouses, layouts below El. 27.0' were essentially the same. Above that level, the outdoor type layout would provide circular weatherproofed generator housings with removable hatches; the semioutdoor type layout would provide a continuous light-framed housing with rectangular removable hatches over the generators and powerhouse gantry cranes straddling the housing; and the indoor type would provide a typical superstructure housing the overhead bridge cranes, as well as the units. These layouts are included in Appendix I as an attachment to letter dated March 12, 1958.

Estimated cost differentials reveal that significant savings in construction costs could be realized by the adoption of the outdoor type powerhouse. Incremental construction costs as compared to the outdoor type were estimated as follows:

| | |
|---|---|
| Semioutdoor | $800,000 |
| Indoor | 2,500,000 |

In these figures, only direct construction costs are considered and overhead is not included. A more detailed description of the three designs, as well as a breakdown of the estimated cost differentials, is included in Appendix V, Conference Notes, February 27, 1958.

It should be particularly noted that, in estimating the cost of the superstructure for the indoor and semioutdoor stations, a minimum type of siding and roofing was assumed. If a more durable type of siding, say concrete, were required, the spread in cost differentials would be considerably greater.

Another important consideration in the comparison of types of powerhouses is the protection afforded the generators and other equipment against inclement weather. All equipment that would require protection, except for the generators, would be on the El. 12.0' floor level and would be well protected regardless of the type of powerhouse. Consequently, the comparison is essentially the degree of protection afforded to the generators against inclement weather.

The semioutdoor powerhouse would have little, if any, advantage over the outdoor type in protecting the generators against weather hazards. The critical exposure would be when the hatches were removed for servicing the units. The generators in both types of powerhouses would be similarly exposed. Therefore, since the semioutdoor powerhouse would have no significant advantage over the outdoor type and would be more costly to construct, the outdoor powerhouse is obviously the better choice.

In the comparison between indoor and outdoor types of powerhouses, it is apparent that the indoor type would afford the greater protection against bad weather; however, the advantage is not as great as appears at first glance. Because the atmosphere would at times be salty, enclosed generators should be used in either case to provide maximum protection against the deleterious effects of salt. Consequently, when units are operating, generators would be afforded equal protection by both types of powerhouses. It is when disassembling and assembling the units that the indoor type would provide the greater protection against the weather. In order to provide protection for the generators of an outdoor powerhouse under these conditions, the powerhouse gantry cranes would be provided with rolling doors to enclose the area under the crane and the unit being serviced would be housed in.

In view of the large difference in cost between the indoor and outdoor types of powerhouses and the fact that the housed-in powerhouse gantry cranes would afford protection to the units when being serviced during inclement weather, decision was reached to adopt the outdoor type of powerhouse for the Passamaquoddy Tidal Power Plant.

GROUPING OF UNITS

In a powerhouse consisting of 30 units, important savings in construction and operating costs can be realized by grouping the units together electrically and mechanically. With this in mind, the design of the elements making up the plant has been developed so as to take full advantage of these savings.

For example, electrically, the generators would be arranged in four groups, each with a step-up transformer. One group of seven and one group of eight would have a high voltage of 138 kv; one group of seven and one group of eight would have a high voltage of 230 kv. An important factor leading to this arrangement was the decision of the Corps of Engineers to provide, from the switchyard, two 138 kv transmission lines to the Canadian system and two 230 kv lines to the United States system.

Similarly, mechanical auxiliaries have been tied together. Each generator would draw its cooling water, fresh water, from a header running the length of the powerhouse and would discharge to a parallel header. These headers, in turn, would be tied to a number of heat exchangers, utilizing salt water, distributed uniformly throughout the length of the powerhouse. A bank of $CO_2$ cylinders would be provided to protect a group of five generators against fire, and one spare bank would be provided for the six banks. Governors would be twin unit cabinet actuators and would be located between alternate units.

CONTROL ROOMS

As a result of grouping the units together electrically, five control rooms would be located in the powerhouse. Four of these have been designated "Group control rooms" and one "Supervisory control room".

Each group control room would be located approximately at the center of a group of generators. Each room would contain a control board from which the group control operator could control the operation of each generator in the group. Switchgear for the generators in the group would be adjacent to the group control room and on the operating floor at El. 12.0'.

The supervisory control room would be located in the center of the powerhouse and would be the operating heart of the plant. From the supervisory board, an operator could control the operation of any one of the 30 units and could also delegate the operation of any unit to the group control operator.

GENERATOR BAYS

The powerhouse would have two main operating levels; one, at El. 12.0', would be the operating floor on which all major items of equipment would be located, except for the generators, main transformers and gantry cranes. These would be located on the other level at El. 27.0', designated the roof deck.

The roof deck would be designed to support 1,000 psf and would be capable of supporting vehicular loads. The design would provide space for vehicular movement along the intake deck and also on the downstream side between the generator housings and parapet wall.

Plate I shows the general arrangement on the roof deck at El. 27.0'. Four 90,000 kva transformers are shown on the intake deck. Five kiosks with doors would be provided along the intake deck for personnel movement between the operating floor and the roof deck. These kiosks would be placed close to the control rooms for ready access to these important areas. Three 10 by 20 ft hatches are also shown on the intake deck. These would be provided for equipment access to and from the operating floor and would be located in generator bays Nos. 9, 15 and 22.

Plate II is a transverse section through the center line of a unit. Space on the intake side of the operating floor level has been allocated principally for electrical equipment. Therefore, the design would provide for power and control cables to be located in the gallery along the upstream wall and electrical equipment, as well as control rooms, to be located in the gallery under the line of main transformers. Large piping headers would be hung from the ceiling in the gallery on the downstream side of the units.

The proposed arrangement of major items of equipment is shown on Plate III. Electrically, the units have been grouped 8-7-7-8, so that the layout for units 1 through 15 is almost symmetrical with that for units 16 through 30. Group control centers have been located at units 4-5, 11-12, 18-19, and 26-27. Supervisory control center has been located at the center of the powerhouse straddling the contraction joint between units 15 and 16. Six banks of $CO_2$ cylinders for generator fire protection have been uniformly spaced along the length of the powerhouse and the seventh, the spare bank, has been located near the center of the plant. Similarly, the 13 heat exchangers for generator cooling water have been spaced along the downstream wall of the powerhouse. Governor actuator cabinets and pressure tanks have been placed between alternate units. A spiral staircase would be provided in each generator bay for access to the scroll case and to the draft tube inspection gallery at El. -43.5'. A unit heater would be provided in each generator bay on the upstream side of the operating floor.

For unwatering a unit, intake and draft tube gate slots would be provided. Three sets of intake gates and three sets of draft tube gates would be provided. No emergency intake gate slot would be provided; however, in the event maintenance to the intake gate slot were required, the structural steel sections, which would serve as guides for trash racks, could also be used for stop logs. Latches for gate dogging would be operated from the intake and draft tube decks and would be located in 30 of the 90 intake slots and in 30 of the 90 draft tube slots.

Trash racks would be located on the face of the intake. The Corps of Engineers indicates that trash would be a relatively minor problem; therefore, no provision has been made for automatic raking. However, a 10-ton capacity rotating jib crane would be provided on the intake gantry crane to aid in the removal of trash that might periodically accumulate.

<u>ERECTION AND SERVICE BAYS</u>

Erection and service facilities would be provided at each end of the powerhouse. It is estimated that, if only one service bay were provided, it would be in continuous use when major maintenance schedules are established. Consequently, to provide for emergencies and to permit scheduling of major maintenance procedures so as to avoid the worst part of winter, a second service bay has been included in the design.

The Corps of Engineers has requested that the service bay on the east end of the powerhouse be considered as the main one. For this reason, the greater part of the maintenance shop equipment would be located at this end. In addition, considerably greater office space would be provided at this end, not only for plant personnel but also for project administrative personnel. A gallery for the reception of visitors would also be included. Therefore, the office building at the east end would be approximately four times larger than the one at the west end.

In developing the layout of the service bays, after space requirements had been established, consideration was given to construction procedures, as well as to operating convenience. In general, the upstream area at El. 27.0' level has been kept free for access to the powerhouse intake deck, the ends of the service bays have been kept free to enable the Contractor to provide additional temporary erection facilities that can be reached by the powerhouse cranes, if desired, and the downstream area at and above the El. 27.0' allocated for office space and visitors' facilities. Plate IV, Plans and Section - Service Bays, shows the general arrangement.

The Corps of Engineers has indicated that the project construction program would be such that all 30 units would go into operation at about the same time. Therefore, time required for powerhouse construction should be held to a minimum, which would require that several units be assembled and erected simultaneously. While space has been provided for the servicing of one unit in each service bay, the enclosed areas have been sized for the assembly of two rotors, as shown on Plate III. This would permit four units to be assembled at one time - four rotors in the enclosed areas and four bearing brackets and four turbines in adjoining unenclosed areas.

Service facilities would be about the same in each service bay. Unwatering and drainage sumps would be provided at each end of the powerhouse. Similarly, shower and locker rooms, first aid rooms, compressor rooms, utility rooms, oil storage and pump rooms, station service substations, maintenance shops with adjoining tool, stock and store rooms, and erection areas would be provided in each service bay. An oil room with pumps and tanks for the Oilostatic cables would be provided in the west service bay, only.

## HYDRAULIC DESIGN

### HYDRAULIC TURBINES AND GOVERNORS

Turbine type, size and setting and dimensions of water passages have been set by the Corps of Engineers in its Interim Report, "Turbine and Generator Studies", dated September, 1957.

The turbines would be of the vertical shaft, single runner, fixed blade propeller type with concrete scroll case and elbow draft tube. Direction of rotation would be clockwise when viewed looking down on the unit. Rated speed would be 40 rpm; runaway speed would be approximately 100 rpm. Center line of turbine distributor would be at El. -9.5' and the elevation of the water surface in the tailrace would vary from 3.5 ft below to 9.5 ft above the center line of the distributor. Turbine discharge diameter would be 320 in.

Provision would be made for limiting the output of the turbine so that generator output would not exceed 12,650 kva rated generator capacity at 0.90 pf plus 15 per cent. Each turbine would be provided with governor operated wicket gates.

Because fresh water supply is limited and costly, turbine packing glands would be designed to operate without the use of water. Turbine manufacturers report that this can be done. One manufacturer stated that on recent designs a grease packed box is being used, lubricated periodically by the centralized lubrication system and that favorable comments have been received from the field.

The governors would be of the oil pressure, relay valve, actuator type with electrically driven speed responsive elements. The governors would be twin unit cabinet actuators, to be located between alternate units and equipped with all necessary indicating and control devices, pressure tanks, sump tank with two motor driven pumping units, gate servomotor oil piping and permanent magnet generator mounted on top of the turbine generator shaft for driving the speed responsive element. The normal operating pressure range would be between 250 and 300 psi and the entire governor oil system would be designed for an operating pressure of 300 psi. Governor capacity has been estimated by the Corps of Engineers to be 270,000 ft-lb. The actuator cabinets and pressure tanks would be located on the El. 12.0' floor between associated turbines.

## GATES, TRASH RACKS AND STOP LOGS

Three sets of intake gates would be provided for the 30 units. Each set would consist of one wheeled and two slide gates. The gates would be approximately 40 ft high and 17 ft-4 in. wide and would be made in two sections to facilitate handling and reduce the required capacity of the intake gate gantry cranes. Guides would be installed in all gate slots. The gates would be handled by the 30 ton intake gantry cranes which would be equipped with lifting beams. When not in use, gates would be stored in the gate slots.

In the event of emergency closure, slide gates would be dropped in the two outside water passageways and then a wheel gate dropped into the middle passageway. With this type of operation, the most severe requirement for closure would occur, if turbine wicket gates were wide open, when the upper section of a slide gate would be just closing the second passageway. Under these conditions, the upper gate section would close under its own weight whenever the gross head on the plant were less than 23 ft. On the basis of the studies by the Corps of Engineers, gross head on the powerhouse would vary between 21 ft maximum and 6 ft minimum. Consequently, emergency closure could be effected at all times.

Three sets of three slide gates each for the draft tubes would be provided for the 30 units. They would be approximately 25 ft high and 17 ft-4 in. wide and would be made in two sections to facilitate handling and reduce required capacity of the rotating jib hoist on the downstream side of each powerhouse gantry crane. Guides would be installed in all gate slots. Lifting beams would be provided for handling the draft tube gates. When not in use, gates would be stored in the gate slots.

To rewater the draft tubes, water would be drawn from an operating draft tube through the unwatering header into the unwatered draft tube.

Marine growth on the intake and draft tube gate guides might increase leakage around the gates when in place and the units unwatered. To prevent marine growth on the gate guides, these guides would be painted with an antifouling paint.

Trash racks would be located at the face of the intake structure. Racks would be placed in slots formed by structural steel sections attached to the upstream pier nosings. These attached steel sections would also serve for retention of stop logs if a dewatering operation should be required for maintenance of intake gates or slots. To prevent marine growth, these sections would be painted with an antifouling paint. Three racks, 15 ft high by 22 ft wide, would be required per water passage, or a total of 273 for the powerhouse, including three spare sections for use during maintenance.

One set of stop logs would be provided for closure of any one intake passageway in case a gate failed or did not operate properly. The stop logs would be designed to operate in steel sections attached to the upstream pier nosings. Each stop log would be handled separately by the 10 ton capacity boom hoist mounted on an upstream corner of each intake gantry crane. A special lifting beam would be used with the hoist in lifting the stop logs and intake trash racks.

POWERHOUSE GANTRY CRANES

Two 220 ton double trolley gantry cranes with spans of 79 ft and operating the full length of the powerhouse, including erection, service and unloading bays, would be provided for handling the generators and turbines during erection and future maintenance. The cranes would also be used for untanking the transformers, installation of pumps, unloading and loading of railroad cars and general construction work.

The cranes would be provided with rolling doors to permit the area under the crane to be enclosed for operation during the winter or inclement weather. Provision would be made for heating and lighting the enclosed area. Distance between the two end doors would be 70 ft to provide walking space around the generator housing when the doors have been rolled down.

A rotating jib crane, 20 ton capacity, would be provided on the downstream side of each gantry crane to permit handling of the draft tube gates. Hoist for this crane would be located inside the gantry crane housing to provide maximum protection against the weather.

A 200 kw Diesel generator set would be installed in each gantry crane to permit the crane to be self-propelled. This would eliminate the need for a costly collector system and the troublesome problem of protecting this system against salty atmosphere.

The maximum loads that cranes would have to lift would be the turbine runner and the generator rotor. Estimated weight of runner is 250,000 lb; estimated weight of rotor is 410,000 lb.

The decision to adopt two cranes was based principally on the estimated requirements of the plant when regular maintenance procedures are established. No precedent for Passamaquoddy exists; consequently, in estimating the frequency at which units would be dismantled for cleaning and repairs, only an approximation could be made. Turbines would be exposed to the corrosive effects of salt water and the generators to an atmosphere which, at times, would contain minute particles of salt. In general, it can be anticipated that maintenance procedures would be more frequent than normally experienced at fresh water plants.

The turbines would be set very low with respect to tail water, so that plant sigma would, at all times, be well above critical values. For this reason, cavitation should be a relatively minor factor in turbine maintenance. Probably the greatest cause for turbine maintenance would be the corrosive effects of salt water, both in terms of repairing damage already done and in performing those preventive measures necessary to defer further corrosion.

The generators would have enclosed cooling systems, since these would offer the greatest protection against the salty atmosphere. However, in spite of this protection, generator maintenance can be expected to be more frequent than normally experienced.

Experience at multiunit fresh water plants indicates that unit outage for major overhaul occurs about once every 10 years. Consequently, if facilities were provided at Passamaquoddy to overhaul each unit completely once every five years, such facilities should be adequate to take care of maintenance problems.

Assuming two months for the dismantling, servicing and reassembling of each unit, one service bay and one powerhouse crane would be kept busy continuously if each of the 30 units were completely serviced once every five years. Therefore, by providing two powerhouse cranes and two service bays, facilities would be available for emergency repairs and for scheduling of major maintenance procedures so as to avoid the winter period when electrical load would be at its greatest and the weather at its worst.

Hook capacity and gantry and trolley speeds would be as follows:

| | |
|---|---|
| <u>Main Hooks</u> | |
| Capacity, each hoist, tons | 110 |
| Capacity of crane, tons | 220 |
| Maximum lift, ft | 80 |
| Hook speed, fpm | 5 |
| <u>Auxiliary Hooks</u> | |
| Capacity, each hoist, tons | 25 |
| Maximum lift, ft | 100 |
| Hook speed, fpm | 25 |
| <u>Rotating Jib Hoist Hook</u> | |
| Capacity, tons | 20 |
| Maximum lift, ft | 120 |
| Hook speed, fpm | 15 |
| Rotation, deg | 180 |
| <u>Gantry</u> | |
| Span, ft | 79 |
| Length, ft | 70 |
| Speed, fpm | 75 |
| Travel distance, ft | 2,700 |
| <u>Trolley</u> | |
| Speed, fpm | 25 |
| Travel distance, ft | 45 |

Each crane would have two trolleys. Each trolley would have a 110 ton main hook and a 25 ton auxiliary hoist hook. For lifting a generator rotor, a lifting beam rated at 210 tons would be connected to the two 110 ton hooks.

<u>INTAKE GANTRY CRANES</u>

Two 30 ton fixed hoist gantry cranes with spans of 10 ft and operating the full length of the powerhouse, including service bays, would be provided for handling the intake gates. In addition, each crane would be provided with a 10 ton auxiliary jib crane pivoted on an upstream leg to rotate through an angle of 180 deg. The jib crane would handle trash racks and emergency stop logs, as well as assist in the removal of trash.

A 20 kw Diesel generator set would be installed in each gantry crane to permit crane to be self-propelled. This would eliminate the need for a costly collector system and the troublesome problem of protecting this system against salty atmosphere.

The maximum load that cranes would have to lift would be when an upper gate section admits water to a scroll case after it has been unwatered. Estimated weight of upper gate section is 30,000 lb; estimated frictional resistance in lifting gate is 25,000 lb. Maximum total lift is, therefore, estimated to be 55,000 lb.

The decision to adopt two cranes was based largely on the need for dropping gates into position as expeditiously as possible whenever a unit is to be unwatered. Gantry travel lengths would be unusually long. Consequently, with only three sets of gates and two sections per gate, considerable time would be consumed, at times, in gantry travel when shifting intake gates from one location to another. This would be the case especially if some of the gate sections should be undergoing maintenance. Two gantry cranes, working as a team, would cut closure time of a single operating crane almost in half. As a third crane would provide little additional benefit, since its operation would interfere with either of the other two cranes, it was concluded that two gantry cranes should be provided.

Hoist capacities, speeds and lifts and gantry speed would be as follows:

Main Hoist

| | |
|---|---|
| Main hoist capacity, tons | 30 |
| Hoist speed, fpm | 10 |
| Maximum lift, ft | 90 |

Rotating Jib Hoist

| | |
|---|---|
| Auxiliary jib hoist capacity, tons | 10 |
| Hoist speed, fpm | 25 |
| Maximum lift, ft | 100 |
| Rotation, deg | 180 |

Gantry

| | |
|---|---|
| Gantry travel, ft | 2,600 |
| Speed, fpm | 100 |

## ARCHITECTURAL AND STRUCTURAL DESIGN

### BASIC DATA AND ASSUMPTIONS

The powerhouse and other structures would be designed in accordance with accepted engineering practice. The architectural and structural design, preparation of drawings and specifications, and selection of materials of construction would be as outlined in Part CXXX, chapters 1, 2 and 3, dated March, 1956, of the Engineering Manual for Civil Works Construction - Hydroelectric Power Plants. All working stresses would conform to those given in Engineering Manual for Civil Works Construction, Part CXXI, Chapter 1, dated May, 1953. Exposure classification "B", "Structures which will be subject to unusually severe weather or exposure to other hazards", has been assumed in all preliminary design work. Wind loads used in design would be as recommended by the American Standards Association in their bulletin A58.1, 1955, American Standard Building Code Requirements for Minimum Design Loads in Buildings and Other Structures.

The controlling elevations, referred to mean sea level, are as follows:

| | |
|---|---|
| Intake deck | 27.0 |
| Intake floor | -40.0 |
| Maximum headwater pool | 13.5 |
| Minimum headwater pool | 3.0 |
| Maximum tail water pool | 0.0 |
| Minimum tail water pool | -13.0 |
| Operating floor | 12.0 |
| Center line distributor | -9.5 |
| Outlet of draft tube (floor) | -65.0 |
| Bottom of draft tube (floor) | -83.0 |

In addition, the maximum tail water level for the design of the powerhouse would be El. 13.5, a level that might be experienced if the tidal gates were inoperative.

Unit weights assumed for the design are as follows:

| | $lb/ft^3$ |
|---|---|
| Fresh water | 62.5 |
| Salt water | 64.0 |
| Concrete | 150.0 |
| Steel | 490.0 |

The design floor and roof live loads, allowable concrete and steel stresses which are to be used in structural design are summarized as follows:

| Design Floor Live Loads | psf |
|---|---|
| Offices, visitors' gallery, toilets, locker rooms, stairways | 100 |
| Main powerhouse and service bay deck at El. 27'-0" | 1,000 or H 20 |
| Main powerhouse and service bay floor at El. 12'-0" and El. 7.00 | 1,000 |

Design live load for roofs would be 50 psf, including snow load.

Special provisions would be made for transformer foundations and gantry crane wheel loadings on the supported deck at El. 27'-0".

The main powerhouse gantry crane wheel loads would be increased by 10 per cent for impact and treated as moving live loads in the design of the floor at El. 27'-0". The intake gantry wheel loads would be increased by 15 per cent to allow for impact. Side thrust at the top of the crane rail would be taken as 7 1/2 per cent of the combined weight of the trolley and the rated load divided equally among the wheels at either side of the runway. Longitudinal runway forces would be considered as 10 per cent of the wheel loads.

All structures would be designed to sustain a wind pressure of 25 psf below El. 17'-0". From El. 17'-0" to El. 36'-0", a wind pressure of 35 psf would be used. From El. 36'-0" to El. 86'-0", a wind pressure of 45 psf would be used. Above El. 86'-0", a wind pressure of 55 psf would be used.

In designing floors, roofs, columns and bracing in any part of the powerhouse, service bays and office buildings for earthquake forces, 10 per cent of the total of the gravity loads above the section being designed should be applied to the structure horizontally in any direction.

In designing for wind loads or earthquake loads alone, or in combination with gravity and other normal working loads, maximum allowable stresses could be increased by 33 1/3 per cent, provided the resulting section is not less than that which would be called for by gravity and normal working loads alone. Wind loads and earthquake loads would not be considered as acting concurrently. The effect of hydrodynamic forces on the powerhouse due to earthquakes should be considered in the design of the monolith. The paper of Mr. H. M. Westerguard entitled "Water Pressure in Dams During Earthquakes", Transactions ASCE, Volume 98, 1933, page 418, should be referred to for method of application of these forces.

Reinforced concrete design would follow the provisions of the American Concrete Institute Building Code Requirements for Reinforced Concrete (ACI 318-57), using concrete having a design ultimate compressive strength at 28 days of 3,000 psi. Due to exposure to severe weather conditions and salt water, design compressive stress would be limited to 750 psi and the extreme fiber stress in tension would not exceed 42 psi. Reinforcing steel would be intermediate grade new billet steel designed for a maximum stress of 16,000 psi.

All permanent structural steel would be designed in accordance with the current provisions of the American Institute of Steel Construction "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings", using as a basic design stress 18,000 psi with the exception of elevator machinery supports which would have a basic design stress of 12,000 psi. A basic design stress of 24,000 psi would be used for temporary steel structures.

A preliminary stability analysis has been made of a typical powerhouse monolith. Full hydrostatic uplift pressure was applied to the base for this analysis. The resultant of all forces was well within the middle third of the base, indicating that the monolith would be stable for any foreseeable combination of wind, earthquake or other forces.

Instructions were received from the Corps of Engineers to assume that the foundations of the powerhouse and service bays would be on sound rock.

Structural design of a preliminary nature was undertaken to determine the relative economy of the outdoor versus semioutdoor or indoor type of station. The results of this investigation which are given in Appendix V, clearly indicated the selection of an outdoor type of powerhouse.

## GENERAL TREATMENT

The powerhouse, service bays and shops would be reinforced concrete structures designed for utility. Simplicity would be the keynote to the architectural treatment and all superficial decorations would be omitted. Table 1, attached, is a Description of Structural Work and includes a description of wall and floor treatment, as well as facilities to be provided for personnel and visitors.

### Powerhouse

The powerhouse would be of outdoor design with an open deck at El. 27'-0" upon which would be the metal housings of the 30 generators, the transformers, the intake gantry cranes and the main powerhouse gantries. Exterior walls would be poured reinforced concrete. The reinforced concrete deck would be covered by a two-ply asbestos felt membrane waterproofing, which, in turn, would be covered by a wearing surface of dense, trap rock granolithic concrete finished with a steel trowel. Openings would be left in the downstream walls for aluminum projected windows for the purpose of providing light and ventilation. The operating floor at El. 12'-0" would have a separately poured wearing surface of granolithic concrete finished with a steel trowel. Access to the operating floor from the open deck would be gained through five poured concrete kiosks which would project above the open deck. Minor maintenance would be facilitated by the provision of three curbed hoisting hatches affording 10 ft by 20 ft clear openings which would normally be covered with protected metal covers on steel frames.

Stair Kiosks

The stair kiosks would have poured concrete walls and roofs. Access to the kiosks would be through industrial steel doors. Doors and frames would be covered by the best protective coating obtainable. Each kiosk would house a reinforced concrete stairway to El. 12'-0". Abrasive nosings would be provided on treads and landings.

Control Rooms

Five control rooms would be provided. Walls would be 8 in. glazed architectural tile presenting a finished appearance inside and out. Glass vision panels would be provided in the upper portion of the walls to permit observation. Floors would be covered with heavy vinyl plastic tile which would meet the cove base of the wall tiles. Ceilings would be covered with acoustic tile secured to the underside of the concrete deck. Each control room would be provided with a toilet and lavatory, clothes closet and supply closet constructed of 4 in. glazed architectural tile and would be equipped with a drinking fountain and a combination electric refrigerator and stove.

Service Bays

At each end of the powerhouse, there would be a service area. During the construction period, these would serve as erection areas for the simultaneous assembly of four major components. Four open hatches served by the main powerhouse gantries would permit transferring heavy components from railroad cars or trucks to the erection bays at El. 7'-0". When not in use, the hatches would be made weathertight with a steel framed protected metal cover. Upon completion of construction, the erection bays could be converted to maintenance areas for scheduled maintenance of heavy equipment, such as gates, which would be facilitated by heavy overhead handling equipment. The exterior walls of the service bays would be of poured concrete construction. Roofs, floors, floor finish and waterproofing would be the same as for the powerhouse. Ceilings would be painted concrete. The interior would be divided as necessary to form compressor rooms, oil storage rooms and shops by means of 8 in. concrete block walls. A 6 ft high dado of battleship gray would extend above the floor. The ceiling and walls above the dado would be painted a light color to reflect light. The oil room would have floors and dado painted with oil resistant paint. Doors and frames would be industrial steel. There would be a drinking fountain in the shop area at each end of the powerhouse.

<u>Locker Rooms and Toilets</u>

A portion of each service area would contain locker rooms and toilets. Interior walls of locker rooms would be glazed architectural tile. Floors would be steel troweled granolithic concrete. The roof and exterior walls would be the same as for the powerhouse. Ceilings would be painted concrete. Forced ventilation would be provided in the locker rooms which would each contain 30 lockers and a drinking fountain. A shower and toilet room would adjoin each locker room. Two stall showers of 4 in. glazed architectural tile with ceramic tile floors and painted ceilings would be provided at each end of the powerhouse. Three water closets in metal enclosures, three lavatories, one 54 in. wash fountain, and two urinals would be installed in each toilet. The toilet room construction and finish would be the same as that for the showers. Doors and frames would be industrial steel.

<u>First Aid Rooms</u>

A first aid room would be provided in each service area. Construction would be similar to that of the locker and shower room, except that a vinyl tile floor and acoustic ceiling would be furnished. A pair of double doors would be used to make a 5 ft wide opening to facilitate the handling of litter cases. Each first aid room would be equipped with a lavatory.

Offices

Office facilities would be provided at each end of the powerhouse. At the east end, the office building would be a two-story structure and would have an elevator serving both office levels and the service level at El. 12'-0". This would be a fully automatic electric combination freight and passenger elevator, having a capacity of 2,000 lb pay load at a speed of 150 fpm. The office building at the west end would be a one-story building without an elevator.

Exterior walls and suspended floors of the offices would be poured reinforced concrete. The roof decks would be 6 in. Flexicore slabs supported on steel rafters. Two inches of Foamglas insulation would be installed on the deck over which a waterproofing of five plys of asbestos felt mopped with asphalt and covered with gravel would be applied. Aluminum projected windows would provide light and ventilation. Floors would be covered with vinyl plastic tile. Ceilings would be vermiculite plastered and painted. Permanent partitions would be painted vermiculite plaster on metal lath. An allowance has been made in the estimate for 1,200 sq ft of movable metal partitions.

Glazed tile toilet rooms with ceramic tile floors would be provided for men and women in the offices at each end of the station. Each women's toilet would have a 6 ft by 8 ft rest room, a water closet and lavatory. Each men's toilet would be equipped with a water closet, urinal and two lavatories. Water closets would be enclosed in metal toilet enclosures. A drinking fountain would be provided in the offices at each end of the powerhouse.

PUBLIC FACILITIES

At the east end of the powerhouse, a portion of the first floor of the office building would serve as a visitors' gallery. The architectural treatment and finish of this portion of the office building would receive special attention so as to present a pleasing appearance to the visiting public. The main entrance to the lobby, which also serves as entrance to the offices, would have a stainless steel door and frame. Picture windows would be provided in two elevations of the visitors' gallery to afford visitors a panoramic view of the powerhouse and its vicinity. A ladies' toilet for visitors would contain a 6 ft by 8 ft rest room, two water closets in metal enclosures, and two lavatories. The men's toilet for visitors would have two water closets in metal enclosures, two urinals and two lavatories. Construction of the visitors' toilet rooms would be similar to that of the offices. A drinking fountain would also be provided in the visitors' area.

## ELECTRICAL DESIGN

### GENERAL ELECTRICAL ARRANGEMENT

Electrically, the generators would be arranged in four groups each with a step-up transformer. One group of seven and one group of eight would have a high voltage of 138 kv; one group of seven and one group of eight would have a high voltage of 230 kv.

The high voltage transmission to the switchyard would be by means of high pressure pipe type cable, the engineering for which is not included in the scope of this report.

A control center with switchgear and control board would be located in the approximate center of each generator group, and a supervisory board from which an operator can control the operation of any one of the 30 units would be in the middle of the powerhouse. The supervisory operator may delegate the operation of any unit to the group control operator.

A 13.8 kv feeder cable would be taken from each group for power supply to the service bays at each end of the powerhouse, two to the west end and two to the east end. From the east end service bay, these cables would be extended for power supply to the tide gates. This extension is not included in the scope of this report.

All switchgear and control equipment would be located at El. 12.

The electrical connections and equipment arrangement are illustrated on the following plates, attached to this report:

| | |
|---|---|
| Plate V | - Main One Line Diagram |
| Plate VI | - 480 V One Line Diagram |
| Plate VII | - Control Equipment Arrangement |
| Plate VIII | - Main Transformer Arrangement |
| Plate IX | - Cable Tray Arrangement |

## MAIN TRANSFORMERS

Three phase, forced oil-air (Type FOA) transformers have been selected on the basis of most economical design combined with proved reliability. All four transformers would be rated 90,000 kva, which is commensurate with the output of eight generators. The rating is based on the net input less active and reactive losses, and taking advantage of the low 24-hr ambient temperature in accordance with the formula given in C57.92 of the ASA Standards. No reduction has been made due to load factor. One step reduced basic insulation level would be used for the windings, but the bushings would have a basic insulation level one step higher than that required by the operating voltage in view of the prevalent atmospheric conditions.

The complete characteristics of the 138 kv transformers would be: 90,000 kva FOA, 3 phase, 13.2-138 kv, delta-wye, 110 kv BIL neutral, 550 kv BIL HT, with 750 kv BIL high tension bushings, impedance approximately 14 per cent, and two full capacity taps above and below rated voltage on high tension side.

The 230 kv transformers would be: 90,000 kva, FOA, 3 phase, 13.2-230 kv, delta-wye, 110 kv BIL neutral, 900 kv BIL HT, with 1,175 kv BIL high tension bushings, impedance approximately 17 per cent, and two full capacity taps above and below rated voltage on high tension side.

The transformers would be designed for minimum width. The lightning arresters would be mounted separately, suspended from a steel arbor above the transformers. On the basis of an effectively grounded system, the 138 kv equipment would have arresters rated 121 kv, and the 230 kv transformers would have 195 kv arresters. The arrangement of the transformers and their connections is illustrated on Plate VIII.

13.8 KV SWITCHGEAR

The Corps of Engineers has furnished information regarding the system interconnections to be used for the transmission lines from the project. Based on this information and on a generator subtransient reactance of 36 per cent and on transformer impedances, the duty on the 13.8 kv switchgear under short circuit conditions has been computed. The results indicate that circuit breakers having an interrupting capacity of 750,000 kva would be required.

Solenoid operated, drawout type air circuit breakers rated 13.8 kv, 1,200 amp, 750,000 kva interrupting capacity in metalclad construction would be used. For each group of seven or eight generators, the switchgear would be arranged in two parallel rows transversely to the long axis of the powerhouse. The bus ties between the two rows would be formed by segregated phase type leads from which isolated phase type leads would be taken vertically to the transformer low voltage side.

No circuit breaker would be used in the transformer connection.

The arrangement of the switchgear is shown on Plate IX.

CONTROL STORAGE BATTERIES

Each group of generators would have its own control storage battery with charger and distribution board. Since the length of direct current circuits would not be excessive, 125 v has been selected as the control voltage and, in view of the frequency of breaker operation which is expected in this power plant, long life nickel-cadmium batteries would be used.

A 92 cell, 150 amp-hr, 8 hr rate battery would supply the operating requirements for switching, control and for emergency lighting, which would be kept to the minimum.

A 7 1/2 kw motor generator set for each battery would be used for charging. Motor generators are preferred over electronic chargers due to their lower sensitivity to fluctuations in the alternating current voltage.

The distribution board would have the necessary control equipment for battery charging and breakers for direct current supply circuits to the switchgear and to the governor cabinets, as well as to the emergency lighting system.

EXCITATION SYSTEMS

Each generator would have a direct connected exciter and pilot exciter; there would be no spare exciter. The main exciter would be rated 200 kw, 250 v. The field circuit breaker would be in the main exciter field. Due to the low speed, 40 rpm, of the generator, the voltage regulator would be of the indirect acting rheostatic type.

The field circuit breaker and the rheostat equipment would be located in a cubicle next to the barrel of each unit.

NEUTRAL GROUNDING AND SURGE PROTECTION

Computations indicate a ratio of approximately 16 between zero sequence reactance and positive sequence subtransient reactance. Neutral grounding by means of resistors would, therefore, be used.

A ground bus with a 10 ohm resistor would be provided for each group of generators and a circuit breaker housing for a breaker of the drawout type, in metalclad construction, would be provided at each generator for connecting one generator of each group to the ground bus. Two circuit breaker elements, however, would be provided for each group of generators for convenience in operation.

Although the power station would be located in an area with an isokeraunic level among the lowest on the continent, it is recognized that the 13.8 kv switchgear and generators would be subject to some exposure to lightning hazard due to the feeders at generator voltage. Two of these would be used for power to the tide gates and the possibility exists that the other two feeders might also be extended outdoors.

Surge protection for the generators is, therefore, deemed advisable and would be provided on each unit. There would be two .25 mfd capacitors and one 15 kv machine type lightning arrester per phase installed as closely as possible to the generator terminals. This equipment would be combined with the generator potential transformers in steel cubicles next to the barrel of each unit.

STATION SERVICE SYSTEMS

For each group of eight generators, the connected motor and lighting loads total 878 kva, and for a group of seven generators, the connected load totals 728 kva. After application of appropriate demand and diversity factors, the combined load for one 7-unit and one 8-unit group totals 910 kva.

Since a continuous auxiliary power supply is essential to the operation of the power station, such a power supply must be reliable and flexible and must also be designed so as to require only a minimum of attention. Consideration was given to the use of house generators of which a minimum of two would be required in order to provide spare capacity. The cost of such machines with their impellers, however, would be high, additional excavation would be required and their operation and maintenance would add to the cost of operating the plant. Although 440 v is well suited for the station auxiliaries, it would be too low when generated and distributed from one source, and a higher voltage, say 2,300 v, would be introduced for distribution of the power.

To fulfill the requirements of service continuity and economy, a supply system has been selected in which a transformer connected to the generator bus would furnish the auxiliary power for the seven or eight units connected to the bus. Each transformer would be capable of carrying the load of its own group, as well as that of an adjacent generator group. The complete rating of each transformer would be 900 kva, 3 phase, 13,200-480 v, self-ventilated, dry type. One spare transformer would be provided.

Each transformer would be connected to a 460 v group bus with drawout type circuit breakers. One feeder in each group would be used for lighting supply; there would be one feeder for each generator and a tie breaker to the adjacent 460 v group bus. The transformer secondary breaker would be 1,200 amp, 50,000 amp interrupting capacity, and all other breakers would be rated 600 amp, 25,000 amp interrupting capacity.

At each generator, there would be a motor control center supplied by the feeder from the 460 v group bus. This center would contain all starters for the unit auxiliary motors and building service motors in the unit area. The starters would be combination molded case air circuit breakers and magnetic contactors. Breakers with 15,000 amp interrupting capacity would be sufficient for the duty during short circuit conditions.

The connected load in the service bays has been estimated to be about 766 kva for the west end and about 917 kva for the east end and 900 kva transformers would be used. Each transformer would be supplied by means of two 13.8 kv feeder cables terminating in a metalclad switchgear cubicle having two 750,000 kva interrupting capacity air circuit breakers. These breakers would be electrically interlocked so that only one breaker per transformer could be closed at the same time. Each transformer would be connected to a 460 v switchgear with draw-out type air circuit breakers. There would be six feeder circuits for supply to lighting transformers, motor control centers and to a distribution center for the heating system.

CONTROL SYSTEMS

Conventional protective relays, instruments and control devices for remote manual control would be provided on a duplex switchboard located adjacent to the circuit breakers, approximately in the center of each unit group. The operator at this control center might, if conditions so required, perform all operations for starting, loading and stopping the units in the group. Indications of trouble would be received on an annunciator for each unit and the operator would be responsible for the action to be taken.

Normally, the control of all units in the station would be the responsibility of the supervisory operator. To this end, a supervisory control board would be located in the approximate center of the station. The equipment on this board would include provisions to perform the following functions for each unit:

Start-Stop
Partial start
Synchronizing (used with partial start)
Gate position
Gate limit
Speed adjustment indication
Generator breaker indication
kw load control
kvar load control
Annunciation (one indication only per unit)
Neutral breaker

A station check and telephone would be common for each group of seven or eight units.

The automatic relay equipment to perform functions of starting, synchronizing and loading and corresponding reverse procedures would be located on the unit group duplex control boards.

Metering equipment for kilowatts and reactive kilovolt-amperes would be located on the unit group boards with telemetering transmitters to the supervisory control center. Kilowatt-hours would be recorded and logged at the group control boards.

A differential water level recorder would be provided in the supervisory control center and water level indicators would be placed at the stilling wells on the upstream and downstream sides.

Space would be available in the supervisory control center for such remote control equipment as the Corps of Engineers may desire to provide in the station for the 138 kv and 230 kv switchyard.

PROTECTIVE RELAYS

The protective relays and devices with their connections which would be applied to the several circuits are illustrated on Plate V. For each circuit, the equipment and its function would be as follows:

Generator

Three differential, one alternating current overvoltage and one exciter overvoltage relay. These relays trip the generator breaker, the exciter breaker and the neutral breaker by means of a multicontact trip relay. Each generator would have a field temperature recorder and a bearing temperature recorder. For each group of seven or eight generators, there would be two stator temperature recorders, on one of which the temperature of the main transformer would also be recorded. Each bearing would have a locally mounted thermal relay for alarm.

In case of $CO_2$ discharge to a generator, the multicontact trip relay would function to open the generator breaker, the exciter field breaker and the neutral breaker and, when the generator differential relays operate, $CO_2$ would be discharged into the machine. The operation of other differential relays would not cause discharge of $CO_2$.

<u>13.8 Kv Feeder Circuits and Supply Circuits to Station Service Transformers</u>

Two induction overload relays and one ground relay would trip the breaker of the affected circuit.

<u>Main Transformers, 13.8 Kv Unit Group Buses and High Tension Cables</u>

Three differential relays, one neutral ground relay and one pilot wire differential relay with three backup relays would trip, by means of multicontact relays, all generator breakers and the 138 kv or 230 kv breaker in the switchyard.

<u>Station Service Group Buses</u>

In case of undervoltage not preceded by overcurrent in the normal supply circuit, undervoltage relays would trip the normal supply breaker and close the tie breaker to an adjacent 460 v group bus.

Except for the 460 v relay equipment which would be located on the low voltage switchgear and the bearing temperature alarm relays which would be near the bearings, all relays and recorders would be mounted on the rear of the generator group control boards.

<u>COMMUNICATION SYSTEMS</u>

A private automatic branch exchange (PABX) telephone system would be provided to serve the station, including the service and office areas. The automatic switching equipment would have capacity for 100 stations and would be located with the attendant's cabinet and the battery equipment adjacent to the supervisory control equipment. Incoming calls would be switched by the supervisory operators.

Stations would be located at each governor cabinet, at the unit group operators' desks, supervisory operator's desk, at the main transformer berths, in the switchyard and in the service areas.

The telephone system would include a code call feature with about 25 signal stations.

In addition to the PABX system, there would be direct communication between the supervisory operator and the group control operators as part of the supervisory control system.

STATION LIGHTING

The primary power supply to the lighting system would be 460 v, 3 phase, and the lighting distribution would be 208Y/120 v, 3 phase, 4-wire. The requirement for each unit area is estimated to be about 32 kw.

From each 460 v group bus, a circuit would be taken through an induction regulator, rated 43.2 kva plus or minus 10 per cent, on the load side of which there would be two 400 amp air circuit breakers. These breakers would supply cable buses extending in each direction almost to the adjacent 460 v group buses. In this manner, the entire length of the powerhouse would be provided with two lighting primary sources, the alternative source for the extreme ends being supplied from the primary lighting systems in the service areas.

At each unit, there would be a 45 kva, 3 phase, dry type, 480-208Y/120 v transformer with taps. The transformer would be connected to both 460 v buses by means of a double throw contactor. If the normal bus voltage should disappear, the contactor would automatically transfer to the alternative source.

Branch circuits from lighting panel boards would cover the unit area and, in addition, would extend into the adjacent unit areas, thus assuring a high degree of continuity.

For the operating areas at El. 12.0', the lighting would be fluorescent type. Incandescent type lights would be used inside the barrel, in the inspection tunnel and at El. 27.0'.

Fixtures would be provided for about 25 ft-c general illumination at El. 12.0'. At the control centers, the intensity would be about 35 ft-c.

In the barrel, fixtures would be evenly spaced to furnish sufficient general illumination, and convenience outlets would be provided for extension lights for close work.

The tunnel would have low level lighting; it is assumed that flashlights would be provided for closer inspection.

At El. 27.0', the fixtures would be recessed in the parapet walls for low level lighting of the upstream and downstream areas of the deck and of the draft tube deck. The center areas would have fixtures supported from the generator housings. No attempt has been made to provide ornamental lighting.

Emergency direct current lighting with permanent fixtures would only be provided at each group control center, at the governor cabinets and at the supervisory control center.

In the service areas, floodlighting would be used for lighting the unloading bays at El. 27.0' and fluorescent lighting for the erection bays and shop areas at El. 7.0'. The rooms downstream from the erection bays at El. 12.0' would have fluorescent or incandescent lighting, depending on the use of the several rooms. The lighting in the oil storage rooms would be incandescent type with vaportight fixtures. Office areas and visitors' facilities would have fluorescent lights.

RACEWAYS AND CONDUCTORS

The 13.8 kv, 5,000 amp connections to the main transformers would be made with isolated phase type leads, supported on a concrete curb at El. 27.0'. Seal-off bushings and drains would be provided where the leads go through the slab, in order to prevent condensation in the interior parts of the leads.

The generator leads would be run in aluminum or equally nonmagnetic metal conduits.

Expanded aluminum trays would be used as far as possible for 440 v and control wiring for ease of access and for reasons of economy. Where conduit must be used, it would be hot-dipped galvanized steel. In general, the conduit would be run exposed, except where walls or slabs must be penetrated. The entire raceway system would be planned to avoid the more than usual possibilities of corrosion.

Due to the wide fluctuations in price levels, the exact type of insulation to be used for power and control cables should be determined at the time of purchase. Based on present conditions, the four 13.8 kv feeders would have 350,000 cir mil, 3-conductor, paper insulated, lead covered cables; the generator leads would be 750,000 cir mil, single conductor copper cables with premium grade, high ozone resistant butyl compound insulation.

The 440 v conductors would have butyl or oil base compound insulation with neoprene or polyvinyl chloride jackets, and butyl or polyethylene insulation would be used for control cables.

GROUNDING SYSTEM

The main ground bus would be a copper bar extending from one end of the station to the other. All grounding connections would be made to this bus.

The grounding electrodes would be lead coated copper plates laid in depressions in the rock on the upstream side of the powerhouse and anchored with rock fill. There would be one electrode per unit. The conductors from the plates to the ground bus would be stranded lead coated copper cable.

Grounding connections from equipment to the bus would be of bare stranded copper cable and made so that two paths to ground would be provided. All connections to the ground bus would be brazed. A direct connection would be made from each lightning arrester and each transformer neutral to the nearest grounding electrode and a tap would be made from this connection to the main ground bus.

No connections would be made from the grounding system to trash racks or gate guides or other metal parts exposed to salt water. Such items would be given cathodic protection which would be essentially nullified by a connection to a large metallic body of different galvanic characteristics.

CATHODIC PROTECTION

In view of the extreme difficulty in making replacements, all steel used for gate guides, trash rack guides and the trash racks themselves would be given cathodic protection.

It has been found that complete protection of steel in relatively still sea water is attained with a current density of 5 ma per sq ft of metal area in the water zone. In fast moving water, the current requirements might easily be as much as four times this amount.

The area of steel requiring protection is about 5,900 sq ft per unit. Using silicon cast iron anodes, a minimum of four anodes would be required on the upstream side and four on the downstream side. This arrangement would require a minimum of one 38 v, 118 amp rectifier. Since operating experience might indicate need for variation between the upstream and downstream sides, two separate rectifiers would be provided, each rated 24 v, 60 amp.

# BUILDING SERVICE DESIGN

## GENERATOR COOLING SYSTEM

### Type of System

A circulating water coil cooling system for heat removal from forced air passages would be incorporated in the generator design to provide a completely sealed recirculating air system within the generator housing. Due to probable deleterious salt content of moisture in the atmosphere under various climatic conditions, it is extremely desirable that an open generator housing should not be used with a cooling system using forced air across the windings derived directly from and discharged to the atmosphere. Cooling of forced air through the generator passages would, therefore, be effected by the provision of circulating water cooling coils.

### Cooling System to be Provided

While it is possible to use salt water as a cooling medium for generator cooling coils, it would present considerable risk of corrosion and consequent leakage of coils with possible resulting hazard and danger to the generator windings and electrical equipment. Special treatment of generator coils and water passages, including neoprene treatment of headers, use of special alloys for coil tubes and use of antimony or other corrosion inhibitors would result in additional cost of generator manufacture. For these reasons, generator manufacturers object to the use of salt water cooling coils in a generator cooling system. Fresh water cooling coils eliminate these hazards and, although heat exchangers and circulating pumps are necessary for circulation of and heat removal from a closed circuit fresh water generator cooling water system, they are, nevertheless, to be preferred.

A closed circuit fresh water cooling system for generator cooling would, therefore, be provided. A system of ducts for cooling the exciter with generator air would be located above the generator seal-off plate. The exciter cooling air would be filtered before being returned to the generator to prevent carbon or other deposits from entering the generator. The generator cooling water would take away both the heat from the generator and exciter and solar heat transmitted through the generator housing. This system would use heat exchangers external to the generator coolers of the shell and tube type in which salt water would pass through the tubes to cool the closed fresh water system. The water requirement for the fresh water cooling system is estimated to be 800 gpm per unit with water entering the generator cooling coils at 86 F and discharging from the coils at 91 F.

Heat exchangers of various sizes capable of handling the cooling load collectively from two, three or five generator units have been considered. The total cost of these various selected combinations to meet the requirements for

30 units would not vary appreciably. It is considered that the best arrangement would be to provide one heat exchanger for each three generator units resulting in 10 heat exchangers for normal use with three spares connected to the system, or a total of 13 heat exchangers.

Under normal operating conditions with sea water at 60 F, the anticipated least favorable sea water condition, each heat exchanger would remove approximately 5,730,000 Btu per hr from three generator cooling systems, or a total of approximately 560 kw per unit, consisting of the following:

Generator and exciter full load losses - 550 kw

Solar heat gain - 10 kw

When a heat exchanger or its pump is out of service for maintenance, piping arrangement would permit generator cooling water to be circulated through the other pumps and heat exchangers. The connected spare pumps and heat exchangers could be put into operation, as required, to serve in place of equipment being serviced or replaced.

With each heat exchanger serving three generator cooling systems, a fresh water circulating pump of 2,400 gpm capacity would be required to maintain proper circulation through the generator water cooling systems. It is planned that each pump would take suction from the generator cooling water return header and discharge directly to its heat exchanger and, from there, the cooled water would be circulated through a common supply header to the cooling coils located in each generator unit.

Each generator unit would be served by single supply and return connections from the common headers. The return connection would include a modulating valve, thermostatically controlled to vary the rate of flow, maintaining a uniform temperature of the generator windings under varying load conditions.

Generator cooling water supply and return common headers would be sectionalized to obtain four sections with gate valves so that repairs in any one section could be isolated. Make-up water to the entire 30 units would be added, automatically, by means of a pressure control to a surge tank connected by a header and branches to each section of the common supply header.

A relief line from the supply header to the return header would be provided in each section of the headers to prevent excessive pressures occurring in the cooling systems whenever a unit might be shut down or the systems otherwise modulated.

A temperature control system would throttle the supply of sea water to the tubes in order to maintain a desired water temperature to the generator coolers under varying load conditions.

Salt water to the heat exchangers would be supplied from the headwater pool and discharge to the tail water pool. The salt water supply system, which includes the supply piping, heat exchanger and discharge piping, would be designed for average plant head conditions. Under minimum plant head conditions between headwater and tail water, a positive head would be obtained to permit the necessary salt water flow without the requirement of pumping. The salt water line to each heat exchanger would be provided with a vacuum pump to prime the line when starting and to maintain the siphon when the system is operating.

Tubes in the heat exchangers for salt water service would be 70-30 copper-nickel with suitable inhibitors to be specified for the metal to be used in the headers and water passages to resist salt water corrosion. Metal surfaces of jackets and headers exposed to salt water, including inside surfaces of supply and return piping for salt water service to heat exchangers, would be neoprene coated. A minimum of this piping would be embedded in mass concrete.

Plates X, XI and XIV, attached, show the arrangement of equipment, piping and connections to generators of generator cooling water system.

## HEATING SYSTEMS

### General

Preliminary computations for the heating loads of the operating floor, based upon design conditions of -10 F outside and 45 F inside, indicate a load of 160,000 Btu per hr per unit or 4,800,000 Btu per hr for 30 units on a shutdown basis. While it is not considered that all 30 units would be shut down simultaneously, each unit would be provided with heating to compensate for building heat losses on a shutdown basis.

For powerhouse heating, a 2-pipe forced circulation hot water system with reverse return is proposed utilizing warm generator cooling water. Each unit area would be provided with one centrifugal fan industrial type heater, incorporating hot water heating coils of sufficient capacity to meet the computed demand. Each group of three unit heaters would be supplied by a circulating pump taking suction from the generator cooling water warm return header. Water from unit heaters would return to the generator cooling water supply header. Each unit heater fan motor would be thermostatically controlled and provision would be made to interlock the operation of each pump with the three unit heaters it serves.

For the west end service bay structure, preliminary computations indicate a total transmission load of 447,000 Btu per hr and an air load of 444,000 Btu per hr based on -10 F outside and 45 F inside for the general areas, 65 F for the maintenance shop and 70 F for office areas.

For the east end service bay structure, preliminary computations indicate a total transmission load of 847,000 Btu per hr and an air load of 536,000 Btu per hr on the same basis.

For heating requirements in the service bays, thermostatically controlled electric resistance heaters would be provided. Heaters for office areas, shower and locker rooms, erection areas, and maintenance rooms would be located in the ventilation duct work. In the office areas, convection type radiant heaters would be provided to supplement heating provided in the ventilation system. In the east end service bay maintenance shop, blower type heaters would be provided to supplement heating provided in the ventilation system.

<u>Service Bay - West End</u>

A total of 223 kw of electric resistance heating would be installed in the ventilation supply or recirculation duct systems. Of this total capacity, 98 kw would be provided to preheat make-up fresh air to 45 F, 32 kw to reheat part of this air to desired higher space temperatures and 93 kw to allow for structural heat losses where only partial or no direct heating is to be provided. A total of 38 kw of electric resistance heating would be installed for direct heating of the office area at El. 27.0' to supplement heating by the ventilation system.

The apportionment of these capacities is as follows:

| Room | Heating in Ventilation System | | Direct Heating |
|---|---|---|---|
| | Air Load, kw | Transmission Load, kw | Transmission Load, kw |
| Preheater, fresh air intake | 98 | | |
| El. 27.0', office area | 8 | 12 | 38 |
| El. 7.0', maintenance shop | 8 | 20 | |
| Corridor | 6 | 26 | |
| Compressor room | | | |
| Utility room | | | |
| Oil storage | | | |
| Shower and locker room and first aid | 10 | 3 | |
| Erection area | | 32 | |
| Oil room for Oilostatic cables | | | |
| Station service substation | — | — | — |
| Total | 130 | 93 | 38 |

| | |
|---|---|
| Air load | 130 kw - 444,000 Btu per hr |
| Transmission load | 131 kw - 447,000 Btu per hr |
| Total electric heating | 261 kw - 891,000 Btu per hr |

Service Bay - East End

A total of 295 kw of electric resistance heating would be installed in the ventilation supply or recirculation duct systems. Of this total capacity, 92 kw would be provided to preheat make-up fresh air to 45 F, 65 kw to reheat part of this air to desired higher space temperatures and 167 kw to allow for structural heat losses where only partial or no direct heating is to be provided. A total of 100 kw of electric resistance heating would be installed for direct heating of the office areas at El. 27.0' and El. 37.5' to supplement heating by the ventilation system.

The apportionment of these capacities is as follows:

| Room | Heating in Ventilation System: Air Load, kw | Heating in Ventilation System: Transmission Load, kw | Direct Heating: Air Load, kw | Direct Heating: Transmission Load, kw |
|---|---|---|---|---|
| Preheater, fresh air intake | 92 | | | |
| El. 37.5', office area | 18 | 32 | | 58 |
| El. 27.0', office and visitors' gallery | 17 | 33 | | 42 |
| El. 7.0', maintenance shop | | 31 | 10 | |
| Corridor | 9 | 18 | | |
| Compressor room | | | | |
| Utility room | | | | |
| Oil storage | | | | |
| Shower and locker room and first aid | 11 | 8 | | |
| Erection area | | 26 | | |
| Station service substation | — | | — | — |
| Total | 147 | 148 | 10 | 100 |

| | | |
|---|---|---|
| Air load | 157 kw - | 536,000 Btu per hr |
| Transmission load | 248 kw - | 847,000 Btu per hr |
| Total electric heating | 405 kw - | 1,383,000 Btu per hr |

Plates X, XI, XII, XIII, and XIV show the arrangement of equipment and piping of heating system.

VENTILATING SYSTEMS

Ventilated sash in the downstream exterior wall of the operating floor, El. 12.0', would be provided throughout the entire length of the powerhouse. Similar fenestration would be provided for the office areas.

For summer conditions, cross ventilation throughout the powerhouse would be obtained by the provision of centrifugal type roof exhaust fans, which would draw air across the operating floor, as required, from open sash. One 3,500 cfm fan with automatic shutter would be provided for each two units of the powerhouse. For the volume served, this air movement would be approximately equal to one air change per hour. During winter operation, sash could be opened slightly throughout the powerhouse and one or more roof exhaust fans put into operation to provide air movement.

In each of the two service bay general areas, similar roof exhaust fans with automatic shutters and connecting duct work would be provided, with a total capacity of 3,500 cfm for each service bay. Separate roof exhaust fans, 2,200 cfm for each of two oil storage rooms and each of two shower, locker and first aid rooms would be provided.

An 800 cfm exhaust fan would be provided for continual exhaust air movement from the compressor and utility rooms in each of the two service bays.

A 1,000 cfm exhaust fan would be provided for summer exhaust ventilation, only, from the office area El. 27.0' in the west service bay. In winter, this air would recirculate to the ventilation supply system.

A 4,400 cfm exhaust fan would be provided for summer exhaust ventilation, only, serving the visitors' gallery and office areas at El. 27.0' and El. 37.5' in the east end service bay. In winter, this air would recirculate to the ventilation supply system.

Mechanical ventilation exhausting to atmosphere would be provided for all toilet areas in the powerhouse and service bay areas.

Two centrifugal type supply fans located in the utility rooms, one 9,800 cfm in the west end service bay and one 13,200 cfm in the east end service bay, together with distribution duct work, would furnish supply air to the general and office areas and visitors' gallery. Provision would be made for recirculating air from maintenance and office areas and visitors' gallery during the winter season.

For the ventilation of the unwatering gallery, three 2,200 cfm propeller fans would be provided. These would exhaust directly from the gallery to three concrete ducts in the structure discharging through floor grilles in the operating floor above. Air would be drawn down the spiral stairs into the unwatering gallery. The air movement in the unwatering gallery would approximate four air changes per hour.

For summer ventilation of the control rooms, centrifugal type roof exhaust fans with automatic shutters would be provided to draw air through the control rooms from the generator room windows. For each of the group control rooms, the exhaust fans would have a capacity of 400 cfm. For the station supervisory control room, the exhaust fan would have a capacity of 1,000 cfm. Fan operation would be by manual control, permitting winter operation whenever necessary. Suitable grilles would be provided for air to enter the control rooms from the generator room.

Plates X, XI, XII, XIII, and XIV show the arrangement of equipment and duct work for ventilating systems.

## FIRE PROTECTION SYSTEMS

### Transformer Fire Protection

Transformers would be protected by an automatic deluge valve spray system. A main 12 in. header would run through the powerhouse in the operating floor on the downstream wall or under the deck slab. At each transformer location, a branch would run from the main header to a strainer, deluge valve and then up through the deck at El. 27.0' to distribution piping, enclosing and protecting the transformer. It is estimated that each transformer system would require a water capacity of 1,750 gpm. The systems would be designed on the basis of only one hazard occurring at any given time. Each transformer system would annunciate to its group control room.

Water for transformer fire protection would be derived from an elevated 125,000 gal storage tank, of which 120,000 gal would be permanently available for fire protection, including fire hose stations. Provision of a water storage tank is outside the scope of this report and the size and location of the tank have been set by the Corps of Engineers to meet estimated construction requirements. The elevated water tank should be located on high ground to the west of the powerhouse at sufficient elevation to produce a delivery pressure of 90 psi at the entrance to the west end of the powerhouse. With the use of a 12 in. fire main, an operating residual pressure of 75 psi would be obtained at the strainer for the transformer deluge valve system near the east end of the powerhouse adjacent to Unit No. 26. Fire pumps would not be used for fire protection facilities.

Fire Hose Stations

Two interior fire hose stations would be provided in each of the two service bays. Each station would include 100 ft of 1 1/2 in. hose, hose nozzle and hose valve and would connect from the fire main serving the transformer deluge system. On the deck level, El. 27.0', a total of six exterior fire hose stations would be provided, one at each of the four transformers and one in each of the two service bays.

$CO_2$ Fire Protection Systems

Separate $CO_2$ fire protection systems would be provided for each room where oil is stored or handled in the east and west end service bays and for each group of five generators. Each system serving the generators and the service bay oil storage rooms would include thirty 75 lb high pressure $CO_2$ cylinders, actuating devices, nozzles and audible alarms. One unconnected spare bank of $CO_2$ cylinders would be provided for the systems serving the generators. The west service bay Oilostatic cables oil room would include six 75 lb high pressure $CO_2$ cylinders, actuating devices, nozzles and audible alarm. Systems would be automatic, but would have a manual control. Systems protecting generators would annunciate to the group control room. Other systems would annunciate to the supervisory control room.

The systems would be installed with all piping nozzles for the high pressure steel rings within the generator housings and for the oil rooms. All control accessories, thermostats and alarms would be included. Systems would be designed for 100 per cent total flooding of hazard areas.

$CO_2$ hand extinguishers would be distributed throughout the powerhouse.

Plates X, XI, XII, XIII, and XIV show the arrangement of equipment and piping of fire protection systems.

<u>OIL SYSTEMS</u>

In each of the oil storage rooms in the east and west end service bays, the following equipment for service to 15 units would be installed:

1 - 4,000 gal clean lubricating and governor oil tank

1 - 4,000 gal dirty lubricating and governor oil tank

1 - 50 gpm, 50 psi discharge pressure transfer pump for governor and lubricating oil service

1 - 1,200 gal per hr centrifuge type oil purifier unit complete with centrifuge, intake and discharge pumps, motor or motors, strainer, electric heater with automatic temperature control, filter press and paper drying oven, including pump and heater, and all necessary appurtenances. The centrifuge in east end service bay would be a permanent installation and the centrifuge in west end service bay would be portable in order to serve switchyard.

The following oil storage equipment would be installed in the west end service bay, only:

1 - 7,000 gal clean transformer oil tank

1 - 7,000 gal dirty transformer oil tank

1 - 100 gpm, 50 psi discharge pressure transfer pump for transformer oil service

The transformer oil system would be provided with piping up to the generator deck, El. 27.0', immediately above the tanks, only. Oil at the transformers would normally be cleaned by portable filter press at the transformer, taking suction and returning oil to the transformer in a cyclical operation. One tankful of clean oil would normally be held in reserve for one transformer.

Two methods of replacing oil in the transformers were considered. One would provide headers from the oil storage rooms to the transformers for the transfer of oil. However, owing to the long lengths of these headers and their infrequent use, a method of transfer of oil by means of tank trailers practiced by public utilities, was considered to be more practicable in this case. When it becomes necessary to replace oil in a transformer, the oil would be drained off to a tank trailer and discharged to the fill line of the dirty oil tank. The clean oil tank would be pumped into a clean tank trailer and the oil carried to the transformer.

Headers and distribution piping for other oil services would be provided, located in the gallery on the tail water side of the operating floor, El. 12.0', connecting between the oil storage rooms and the units. Supply and return lines would be pressure lines as it is not possible to obtain conditions for gravity flow. A portable oil pump would be provided to return oil from the turbine guide bearing and thrust bearing oil sumps to the dirty oil tanks in the service bays.

Oil piping headers would be sectionalized with gate valves to obtain four sections so that repairs in any one section could be isolated.

Oilostatic cables would run under the intake deck slab near the upstream wall. The oil handling room for Oilostatic cables would be located in the west end service bay adjoining the maintenance shop and erection area.

Plates X, XI, XII, XIII, and XIV show the arrangement of equipment and piping of oil systems.

COMPRESSED AIR SYSTEMS

Compressed air equipment, 100 psi, would be provided for each 15 units for service to generator brakes, utility tools, and plant control systems. The equipment for each 15 units would consist of two 50 hp compressors, motors, suitable silencers and one low pressure compressed air receiver having a capacity of about 200 cu ft, all of which would comprise, with distribution piping, one integrated system. One of these systems would be located in each of the compressor rooms in the east end and west end service bays.

Compressed air equipment, 300 psi, for each 15 units for service to governor oil tanks would consist of one 30 hp compressor and motor and one high pressure compressed air receiver having a capacity of 30 cu ft. One of these systems would be located in each of the compressor rooms in the east end and west end service bays.

Each system would be provided with air cooled intercoolers and water cooled aftercoolers to ensure efficient moisture removal.

Main low pressure and high pressure distribution mains would extend along the downstream piping gallery supported from the ceiling slab. Compressed air piping headers would be sectionalized with gate valves to obtain four sections so that repairs in any one section could be isolated.

Plates X, XI, XII, XIII, and XIV show the arrangement of equipment and piping of compressed air systems.

POWERHOUSE DRAINAGE SYSTEMS

A trench drainage system would be provided from the operating floor level, El. 12.0', with trenches on the inside of the headwater and tail water walls. A drain from the headwater wall trench would cross the operating floor between each two units with intermediate drain connections to a vertical drop from the tail water wall trench leading to a collecting header below the unwatering gallery. The drainage header would discharge to powerhouse drainage sumps, one located in the east end service bay and one in the west end service bay adjacent to the unwatering sumps.

The unwatering gallery would similarly be provided with a drainage trench with runoff drains and connections to the collecting header. One of these drains would be provided for each two units.

Each drainage sump would accommodate one vertical turbine pump which would operate by a float control. While it is not possible to compute the amount of drainage discharge from the total drainage system, it is, however, considered that one 500 gpm drainage pump in each sump should be of adequate capacity to handle the discharge on an intermittent pumping basis. To provide maximum protection against flooding the drainage sump, an interconnection to the unwatering sump would be provided. This interconnection would have check and shutoff valves. The pumping discharge head would allow for discharge to the tailrace under all water level conditions, including extreme high tail water.

Deck drainage from the generator deck, El. 27.0', would be provided. Consideration was given to the use of scupper drains under gantry rails, but this idea was discarded since it would require raising the rails higher than is believed desirable.

No seepage drainage would be provided as the operating areas of the structure are substantially above all maximum high water conditions and, therefore, seepage through the upper structure should be negligible.

Drainage from contraction joints would be a structural feature and the station drainage system would be designed to receive the runoff from such contraction joint drainage.

Plates XI, XII, XIII, and XIV show the arrangement of equipment and piping of powerhouse drainage systems.

UNWATERING SYSTEM

A level 24 in. unwatering header would be run from end to end of the station, discharging at each end to the unwatering sumps in the east and west end service bays. In the draft tube for each unit, a 20 in. plug drain valve with non-rising stem and spigot end outlet would connect to a 20 in. by 24 in. tee in the unwatering header immediately below. The plug drain valve would be located in an alcove in one of the draft tube internal piers, with an extended operating stem to the unwatering gallery above.

The total volume of water passages in any one unit is estimated as follows:

| | cu ft |
|---|---|
| Intake | 105,000 |
| Scroll case | 61,000 |
| Draft tube | 87,000 |
| Total | 253,000 |

The total volume of water to be unwatered is less than 253,000 cu ft, the unwatered volume being set by the tail water level at the time the final draft tube gate is dropped into place.

It would be necessary to provide one 150 hp, 5,000 gpm pump with 100 ft discharge head for each of the two unwatering sumps located in the two service bays. The two unwatering pumps would be of the vertical turbine type. Selection is based on an approximate allowed 3 hr unwatering period for one unit assuming no gate leakage and with pumps in service.

Plates XI, XII, XIII, and XIV show the arrangement of equipment and piping of unwatering system.

PLUMBING SYSTEM

Equipment

Shower and locker rooms would be located in each of the service bays and each would contain:

Lockers for 30 men
3 - Water closets
2 - Urinals
3 - Lavatories
1 - Bradley wash fountain, 54 in. diam
2 - Stall showers

For each area, a hot water storage tank and heater would be located in the adjacent utility rooms. A vertical storage heater with a storage capacity of about 400 gal and with electric immersion heater elements would be provided which would also serve toilet areas for offices and visitors.

Five toilet rooms would also be provided in the powerhouse, one for each control room area. Each of these toilets would include one water closet and one lavatory. An 8 gal electric storage heater would be provided for each toilet room.

For visitors, toilet rooms would be provided, including two water closets and two lavatories for women, and two water closets, two lavatories and two urinals for men.

In each office area, toilet rooms would be provided, one for men, including one water closet, two lavatories and one urinal; and one for women, including one water closet and one lavatory.

One drinking water cooler would be provided adjacent to each toilet area and in each locker room.

Water Facilities

The water supply would be derived from the elevated water storage tank having a total capacity of 125,000 gal, of which 5,000 gal would be available for domestic use. The use of sea water for flushing sanitary fixtures has been considered, but this would require duplicate piping installation and elevated salt water tanks and pumps to provide the necessary head for service to fixtures. As the usage factor would normally be low, it is anticipated that the total water requirement for all plumbing fixtures should not exceed 150 gpm for short periods, only, and 5,000 gal water storage capacity should be adequate.

The water storage tank would be located at the west end of the powerhouse.

Sanitary Wastes

With normal high tail water controlled to El. 0.0', sanitary wastes would discharge by gravity to the tail water. Provision would have to be made, however, against an extreme high tail water elevation of 13.5 ft, a level that might be reached if the tidal gates should be inoperative. To provide for this condition, fixtures in the control room toilets would be set at an elevation to preclude backflow. Fixtures in the service bay areas would drain to septic tanks. Discharge from each septic tank would be to a small collection basin housing a bilge pump. When the tail water is at a low elevation, normal flow from this pump basin would be by gravity to the tailrace.

The gravity discharge line from the basin would be protected from backflow from high tail water by a check valve and gate valve, the latter normally open for gravity flow. During high tail water conditions, the effluent level in the basin would rise when gravity discharge becomes inoperable and a high level alarm would indicate the necessity of closing the gravity line gate valve as additional protection to the check valve against backflow. At the same time, a float control in the bilge pump basin would actuate the pump to dispel the contents of the basin by separate pressure discharge lines to the tailrace. It is anticipated that the occurrence of high tail water and consequent pumping of the effluent would be extremely remote and that gravity discharge would normally prevail.

Plates X, XI, XII, XIII, and XIV show the arrangement of equipment and piping of the plumbing system.

## DECK WASHING AND SNOW REMOVAL SYSTEMS

For deck washdown facilities, exterior fire protection hose stations located on the deck, El. 27.0', would be used.

Two 200 ft lengths of portable 1 in. rubber covered, rubber lined fire hose, with adjustable spray nozzles, would be provided, one in each of the service bays, with factory type hose reel carts.

Two vacuum type snow blowing removal machines of the airport runway type would be provided for snow removal from the deck and right of way areas of the generator deck, El. 27.0'.

## TRANSFORMER PIT DRAINAGE

A drain would be provided below each transformer to carry the discharge of transformer fire protection deluge water with possible mixture of oil. Pits filled with crushed rock would be provided under each transformer. Pit drainage of water and oil would be discharged to the tail water side of the powerhouse. Scuppers would be provided through structural supports of transformer rails for passage of water from outside areas to the central drain.

No provision would be made to salvage any oil from a ruptured or leaking oil system, nor to prevent this oil from entering the sea water.

Plate XI shows the arrangement of transformer pit drainage piping.

WATER LEVEL RECORDING EQUIPMENT

One 24 in. stilling well for headwater level recording and one 24 in. stilling well for tail water level recording would be provided. These wells would be located in the service bay at the east end of the powerhouse, with piping from the bases of the stilling wells connecting to headwater and tail water, respectively.

Stilling wells would be provided with floats, counterweights, check calibration tapes with immersion weights, direct reading dials and Selsyn repeaters to relay readings to graphic recorders and visual reading dials in the control room.

MAINTENANCE SHOP EQUIPMENT

General

Maintenance shops would be located in both service bays; the one at the east end of the powerhouse would be regarded as the principal maintenance shop and that at the west end of the powerhouse would be regarded as the secondary or auxiliary maintenance shop. The east end shop would be designed to handle both electrical and mechanical equipment.

East End Maintenance Shop

The following equipment would be included for the east end maintenance shop:

1 - Hack saw, 10 in. by 10 in.
1 - Tap and tool grinder
1 - 24 in. shaper
1 - 21 in. drill press
1 - 2 in. by 12 in. pedestal grinder
1 - Arbor press, about 60 tons
1 - Workbench, about 20 ft long
2 - Workbenches, about 8 ft long
1 - Pipe threading machine
1 - Engine lathe, about 14 in.
1 - Engine lathe, about 9 in.
1 - Bench lathe
1 - Forge
2 - Pedestal drills
1 - Oven
1 - Arc welder, about 400 amp
2 - Bench grinders

A 5 ton bridge crane would be used in the east end maintenance shop.

West End Maintenance Shop

The following equipment would be included for the west end maintenance shop:

2 - Workbenches, about 8 ft long
1 - Portable pipe threading machine
1 - Floor drill grinder, about 1/8 in. by 2 1/2 in.
1 - Hack saw, 9 in. by 9 in.
1 - Bench grinder

A 5 ton bridge crane would be used in the west end maintenance shop.

Plates XII and XIII show the arrangement of maintenance shop equipment.

## COST ESTIMATE

### GENERAL

The cost estimate has been based on prices prevailing in the United States as of January, 1958, and reflects a contractor's bid price for a complete and operating powerhouse.

Normal contingencies have not been included in the estimate. It is intended that, when the Corps of Engineers prepares its over-all project cost estimate, an item for contingencies will be included that will cover the powerhouse, as well as the other elements making up the complete project.

The form followed in the preparation of the estimate is, in general, that outlined in Federal Power Commission Form No. 6 (Rev. 1-56) classification.

The estimate includes a structure to house 30 hydraulic turbine generating units, each with a name plate rating of 10,000 kw, a service bay, together with an unloading bay at each end of the powerhouse, and all necessary auxiliary mechanical and electrical equipment up to and including the main transformers. A two-story superstructure at the east end is also included and a one-story superstructure at the west end to provide office facilities for plant and project personnel and to provide nominal facilities for visitors.

The estimate does not include the cost of sea water diversion and unwatering, excavation, backfill, drilling and grouting of powerhouse foundation rock, fresh water, high tension cables from transformers to switchyard, nor the switchyard itself, since these items will be included in the cost estimate of the Corps of Engineers covering other elements of the project. However, an allowance has been included for preparing the excavated surfaces for concrete and for pumping during powerhouse construction.

It has been assumed that the contractor would purchase all materials and equipment, except the generators and turbines which would be purchased by the Corps of Engineers. The Corps has estimated the cost of generators and turbines as follows:

| | |
|---|---|
| Generators, including exciter and erection | $1,000,000 each |
| Turbines, including governing equipment, but not erection | $1,000,000 each |

On this basis, the estimate includes the contractor's direct and indirect costs for material, equipment and labor for all items, except the generators and turbines. For these two items, the estimate includes contractor's direct and indirect costs for erection only of the turbines and governors and includes nothing for the contractor for the generators.

It is estimated that construction of the powerhouse would take three years, as shown on Plate XV, Construction Progress Chart, attached.

UNIT COSTS

Unit cost figures include all labor, material, equipment and the contractor's entire costs, including overhead and profit. They do not include the costs of design and field engineering nor the costs of Corps of Engineers' supervision of construction.

Labor rates representative of those prevailing in the Bangor and Portland, Maine area have been furnished by the Corps of Engineers and are given in Table 2, attached.

The unit cost figures include all direct and indirect costs that would be incurred by a contractor. The Corps of Engineers has prescribed standards for setting up the unit costs as follows:

"a. All cost estimates will be based on prices prevailing in United States in January 1958;

b. Unit prices will be representative of prices expected to be bid under competition by a reputable contractor for the work involved and should include all costs incurred by him, including a reasonable profit;

c. The work week per shift will be assumed to be six 8-hour days with time and one-half after 40 hours;

d. Wage rates will be as listed on Disposition Form dated 6 May 1958, subject "Wage Rates to be Used for the Passamaquoddy Tidal Power Project Cost Estimates". A copy was furnished Stone & Webster representatives;

e. An allowance of 10 percent of the labor costs will be made for insurance, taxes, and fringe benefits in connection with labor on all classifications, except that on dredges which will be 15 percent;

f. Material and equipment prices will be obtained from suppliers, trade magazines and records;

g. All materials, equipment and labor used in connection with the project will be exempt from sales taxes;

h. Plant rental rates will be based on contractor rental charge practice if such rental charges are known. Otherwise, rental rates for plant which would be ordinary equipment of a contractor qualified to perform the work on the project will be based on the average annual cost to contractors of owning and maintaining construction equipment as contained in the bulletin titled "Contractors Equipment Ownership Expense", published by the Associated General Contractors of America, Inc., Munsey Building, Washington, D. C. The cost of small tools will be estimated as 5 percent of the labor cost required for the item and shall be entered as a plant cost;

i. Indirect costs are made up of distributive and overhead costs which by their nature cannot readily be charged directly as a cost against any payment item in the bid schedule and must, therefore, be distributed as a general cost against all payment items of a particular feature. Care must be taken to insure that all costs that can be charged directly to one or more contract payment items are so charged and not included as a distributed cost. All applicable indirect costs will be estimated separately and summarized for distribution on a percentage basis to arrive at the unit costs;

(1) Distributive costs may consist of the following which will be computed separately and added to the overhead costs listed in subparagraph i(2) to arrive at the total indirect costs:

(a) Mobilization and demobilization of equipment,

(b) Mobilization and demobilization of personnel,

(c) Field office building,

(d) Shops and warehouses,

(e) Construction roads and maintenance,

(f) Utilities;

(2) Overhead cost will consist of the following items and will be 15 percent of the direct costs:

(a) Supervision, including salaries of supervisors, engineers, timekeepers, purchasing agent, clerks, etc.,

(b) Transportation of supervisory and office personnel,

(c) Office supplies and communications,

(d) Interest on capital invested. (Payrolls and materials),

(e) Home office expense,

(f) Bonds;

j. The allowance for contractor's profit in the unit costs should be 10 percent of all the other costs making the unit cost."

On the basis of these standards, the following distribution of direct and indirect costs has been used:

| | | Per Cent |
|---|---|---|
| Direct Cost | | 100 |
| Added to Direct Costs | | 19 |
| Insurance, Taxes, Benefits | 4* | |
| Small Tools | 2* | |
| Contractor's Plant | 10 | |
| Distributive Costs | 1 | |
| Estimating Omissions | 2 | |
| Overhead Costs | | 15 |
| Subtotal | | 134 |
| Contractor's Profit (on subtotal) | | 10 |

*Based on labor pay roll being 40 per cent of Direct Cost.

ESTIMATED CONSTRUCTION COST

A detailed construction cost estimate is presented in Table 3. This estimate is summarized as follows:

| | |
|---|---|
| Power Plant Structures and Improvements | $48,957,000 |
| Intake Gates and Appurtenances | 3,264,000 |
| Draft Tube Gates and Appurtenances | 1,231,000 |
| Turbines and Generators | 65,969,000 |
| Accessory Electric Equipment | 5,816,000 |
| Miscellaneous Power Plant Equipment | 2,493,000 |
| Substation and Switching Station Equipment | 2,270,000 |
| Total | $130,000,000 |

# DESCRIPTION OF POWERHOUSE STRUCTURAL WORK
## PASSAMAQUODDY TIDAL POWER PROJECT
## CORPS OF ENGINEERS, U.S. ARMY

| | Compressor Rooms, Shops, Erection Bays | Oil Storage Room | Locker Rooms | Shower Rooms | Toilets | First-aid Rooms | Control Rooms | Powerhouse (Below El. 27.0) | Stair Kiosks | Offices | Visitors' Gallery |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 1 | 5 | 2 | 1 |
| Personnel | 18 | 0 | Lockers for 30 men | Showers for 18 men | Toilets for 18 men | 0 | 6 men, 4 shifts<br>24 | 4 men, 4 shifts<br>16 | 0 | 4 men<br>5 women | - |
| Exterior walls | - - - - - - Poured concrete - - - - - - | | | | | | None | Poured concrete | - - - - - 8" poured concrete - - - - - | | |
| Roof deck | - - - - - - Poured concrete with membrane waterproofing - - - - - - | | | | | | | | | - - - - 6" Flexicore - - - - | |
| Roofing | None | None | None | None | None | None | None | None | None | 5-ply asbestos felt with asphalt and gravel | |
| Flashing | None | None | None | None | None | None | None | None | - - - - - 16 oz copper - - - - - | | |
| Insulation - Roof | None | None | None | None | None | None | None | None | None | - - - - 2" Foamglas - - - - | |
| Floor finish | - - - - Granolithic - - - - | | | - - Ceramic tile - - | | Vinyl tile | Vinyl tile | Granolithic | Granolithic | - - - - Vinyl tile - - - - | |
| Ceiling | - - - - Painted concrete - - - - | | - - - - Concrete - - - - | | | - - Acoustic tile - - | | None | None | - - - Vermiculite plaster, painted - - - | |
| Interior walls | - - - - 8" concrete block - - - - | | - - - - - - 8" glazed tile - - - - - - | | | | | None | None | Metal lath, vermiculite plaster, painted. Allow 1,200 sq ft of movable metal partitions in office area | |
| **Doors** | | | | | | | | | | | |
| Exterior | None | None | None | None | None | None | None | None | - - Industrial steel doors and frames - - | Provide a stainless steel door and frame on main entrance | |
| Interior | - - - - Industrial steel doors and frames - - - - | | | None | - Industrial steel doors and frames - | | | None | - - - - - - Industrial steel doors and frames - - - - - - | | |
| Windows | None | None | None | None | None | None | Glass vision panels | Aluminum projected | None | - - - - - - Aluminum projected - - - - - - | |
| **Toilets** | | | | | | | | | | | |
| Stalls | | | | | Metal | | 4" glazed tile | | | Metal | |
| Fixtures | 1 drinking fountain | | 1 drinking fountain | 2 glazed tile stall showers | 3 W.C.<br>3 lavatories<br>1 54" wash fountain<br>2 urinals | 1 lavatory | 1 W.C.<br>1 lavatory<br>1 drinking fountain | | | Men / Women | Men / Women |
| W.C. | | | | | | | | | | 1 / 1 | 2 / 2 |
| Lavatories | | | | | | | | | | 2 / 1 | 2 / 2 |
| Urinals | | | | | | | | | | 1 / | 2 / |
| Drinking fountain | | | | | | | | | | 1 | 1 |
| Hatch covers | Steel frame with steel plate cover and protective coating - 4 req'd | | | | | | | Steel frame with steel plate cover and protective coating - 5 req'd, 8' x 8' | | | |
| Remarks | Paint walls with 6' dado. Continue ceiling paint down walls to meet dado | Paint floor and 6' dado on walls with oil-resistant paint | Provide forced ventilation | Paint ceiling | Paint ceiling | Provide 5' wide double door | Provide tile toilet, clothes and supply closet at each control room | Provide a combination electric refrigerator and stove at each control station | | Provide rest room 6' x 8' in women's toilet. Ceramic tile floors and walls in toilets.<br><br>Provide 2,000 lb passenger and freight elevator at Eastport end only | |

## LABOR RATES
## PASSAMAQUODDY TIDAL POWER PROJECT
## CORPS OF ENGINEERS, U.S. ARMY

| | Rates |
|---|---|
| Asbestos workers | $3.60 |
| Boilermakers | 3.60 |
| Bricklayers | 3.25 |
| Carpenters | 2.75 |
| Cement finishers | 3.25 |
| Electricians | 2.90 |
| Elevator constructors | 3.10 |
| Glaziers | 2.25 |
| Ironworkers, structural | 3.45 |
| Ironworkers, ornamental | 3.45 |
| Ironworkers, reinforcing | 3.15 |
| Laborers | |
| Laborers | 1.85 |
| Air tool operators | 2.25 |
| Blasters and powdermen | 2.85 |
| Lathers | 3.15 |
| Lead burners | 3.75 |
| Linemen | 2.90 |
| Linoleum layers | 2.50 |
| Marble setters | 3.25 |
| Millwrights | 2.60 |
| Painters | |
| Brush | 2.05 |
| Spray | 2.30 |
| Structural steel | 2.30 |
| Piledrivermen | 2.50 |
| Pipe layers | 2.25 |
| Plasterers | 3.25 |
| Plumbers | 2.85 |
| Power equipment operators | |
| Bulldozers | 3.50 |
| Cement, concrete pavers | 3.50 |
| Cranes | 3.50 |
| Derricks | 3.50 |
| Dragline machines | 3.50 |
| Elevating graders | 3.50 |
| Elevator towers | 3.50 |
| Grader | 3.50 |
| Hoisting engines | 3.50 |
| Mechanical hoists | 3.50 |
| Mucking machines (when used in tunnels) | 3.50 |
| Pavement breakers | 3.50 |
| Pile drivers | 3.50 |
| Power shovels | 3.50 |
| Pumpcrete machines | 3.50 |
| Scoopmobiles (when used as digging and loading machines) | 3.50 |

| | Rates |
|---|---|
| Power equipment operators (Cont'd) | |
| Shaft hoists | $3.50 |
| Shoveldozers | 3.50 |
| Three drum machines | 3.50 |
| Tractors | 3.50 |
| Trench hoes | 3.50 |
| Trenching machines | 3.50 |
| Maintenance engineers | 3.10 |
| Pumps | 3.00 |
| Compressors | 3.00 |
| Welding machines | 3.00 |
| Concrete vibrators | 3.00 |
| Lighting plants | 3.00 |
| Heaters (power driven) | 3.00 |
| Assistants or firemen on steam shovels, cranes, pile-driving towers or three drum machines | 2.90 |
| Assistants or oilers on other than steam power shovels or cranes | 2.50 |
| Roofers | 2.50 |
| Sheet metalworkers | 2.75 |
| Soft floor layers | 2.50 |
| Sprinkler fitters | 3.35 |
| Steam fitters | 2.85 |
| Stone masons | 3.25 |
| Terrazzo workers | 3.25 |
| Tile setters | 3.25 |
| Truck drivers | |
| 2 axle equipment | 1.90 |
| 3 axle equipment, including lowbeds | 2.05 |
| Semitrailers | 2.25 |
| Specialized earth moving equipment | 2.25 |
| Welders - receive rate prescribed for craft performing operation to which welding is incidental | |
| Riggers - receive rate prescribed for craft performing operation to which rigging is incidental | |

These wage rates are straight hourly wage rates representative of those prevailing in the Bangor and Portland, Maine area as of January 1958.

# ESTIMATED CONSTRUCTION COST
# POWERHOUSE
# PASSAMAQUODDY TIDAL POWER PROJECT
# CORPS OF ENGINEERS, U.S. ARMY

## SUMMARY

| Acct. No. | Description | Total |
|---|---|---|
| 321 | Power Plant Structures and Improvements | $48,957,000 |
| 322.6 | Intake Gates and Appurtenances | 3,264,000 |
| 322.9 | Draft Tube Gates and Appurtenances | 1,231,000 |
| 323 | Turbines and Generators | 65,969,000 |
| 324 | Accessory Electric Equipment | 5,816,000 |
| 325 | Miscellaneous Power Plant Equipment | 2,493,000 |
| 343 | Substation and Switching Station Equipment | 2,270,000 |
| | Total | $130,000,000 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 321 | Power Plant Structures and Improvements | | | | |
| .1 | Powerhouse, Incl. Headworks, Tailworks, Service Areas, Office Buildings | | | | |
| .11 | River diversion, cofferdam and unwatering | | | Not Included | |
| .112 | Pumping during construction | Allowance | | | $350,000 |
| .12 | Excavation | | | Not Included | |
| .13 | Foundation Preparation | | | | |
| .131 &) .132 ) | Drilling and grouting | | | Not Included | |
| .134 | Drain piping below concrete | | | Not Required | |
| .135 | Preparing excavated rock surfaces for concrete | 585,000 | sq ft | $1.00 | 585,000 |
| .14 | Footings | | | Not Required | |
| .15 | Substructure | | | | |
| .151 | Concrete, Incl. Forms and Reinforcing | | | | |
| .1511 | Forms | | | | |
| .15111 | Forms - Straight | | | | |
| | Service bays | 200,000 | sq ft | 2.25 | 450,000 |
| | Powerhouse | 2,700,000 | sq ft | 2.25 | 6,075,000 |
| | Total, Acct. 321.15111 | | | | $6,525,000 |
| .15112 | Forms - Curved | | | | |
| | Powerhouse | | | | |
| | Intake | 325,000 | sq ft | 3.35 | $1,088,750 |
| | Scroll case | 405,000 | sq ft | 5.50 | 2,227,500 |
| | Draft tubes | 290,000 | sq ft | 3.35 | 971,500 |
| | Spiral stair case | 35,000 | sq ft | 1.75 | 61,250 |
| | Total, Acct. 321.15112 | | | | $4,349,000 |
| | Total, Acct. 321.1511 | | | | $10,874,000 |
| .1512 | Reinforcing steel | 46,300 | tons | 380.00 | $17,594,000 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 321 | Power Plant Structures and Improvements (Cont'd) | | | | |
| .1513 | Concrete | | | | |
| .15131 | Aggregate, Incl. Mixing, Placing and Curing | | | | |
| | Service Bays | | | | |
| | Mass concrete (slabs on ground) | 8,400 | cu yd | $15.00 | $126,000 |
| | Walls | 7,000 | cu yd | 18.00 | 126,000 |
| | Columns, beams and supported slabs | 5,600 | cu yd | 24.00± | 134,500 |
| | Powerhouse | | | | |
| | Below operating floor | 600,000 | cu yd | 14.75 | 8,850,000 |
| | Above operating floor | 58,500 | cu yd | 21.50± | 1,258,000 |
| | Total, Acct. 321.15131 | | | | $10,494,500 |
| .15132 | Cement (at 470 lb per cu yd concrete) | 850,000 | bbl | 7.20 | $6,120,000 |
| | Total, Acct. 321.1513 | | | | $16,614,500 |
| .1517 | Water Stops and Seals | | | | |
| | Vinyl water stops | 13,150 | lin ft | 5.00 | $65,750 |
| | Asphalt seals | 4,400 | lin ft | 4.50 | 19,800 |
| | Painted joints (full section) | 48,300 | sq yd | 2.00 | 96,600 |
| | Total, Acct. 321.1517 | | | | $182,150 |
| .1519 | Miscellaneous Block-outs, Cutting and Patching | | | | |
| | Powerhouse (allowance) | 30 | each | 5,000 | $150,000 |
| | Service bays (allowance) | 2 | each | 2,000 | 4,000 |
| | Total, Acct. 321.1519 | | | | $154,000 |
| | Total, Acct. 321.15 | | | | $45,418,650 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 321 | Power Plant Structures and Improvements (Cont'd) | | | | |
| .16 | Superstructure | | | | |
| .161 | Structural Steel and Miscellaneous Iron | | | | |
| | Service Bays | | | | |
| | Crane girders and supports | 46 | tons | $475.00 | $21,850 |
| | Steelwork for Flexicore roofs | 6 | tons | 550.00 | 3,300 |
| | Crane Rails, Fastenings, Bumpers | | | | |
| | Intake gantry (175 lb rail) | 170 | tons) | | |
| | Powerhouse gantry (175 lb rail) | 175 | tons) | 475.00 | 167,675 |
| | Service bay cranes (40 lb) | 6 | tons) | | |
| | Transformer rails | 2 | tons) | | |
| | Transformer transfer car | 1 | | | 10,000 |
| | Railroad track, east side unloading bay | 60 | l.f.tr. | 15.00 | 900 |
| | Hatch Covers (Protected Metal on Steel Frame) (Gr. 27.0) | | | | |
| | Erection bays | 6,400 | sq ft) | | |
| | Access to unwatering pumps | 280 | sq ft) | 6.50 | 47,320 |
| | Powerhouse equipment access | 600 | sq ft) | | |
| | Checkered Plate Covers, Incl. Frames | | | | |
| | Access to unwatering gallery | 72 | sq ft) | 8.00 | 900 |
| | Access to sumps | 36 | sq ft) | | |
| | Drainage Trench Grating Covers and Frames | | | | |
| | Angle frames | 18 | tons | 600.00 | 10,800 |
| | Covers - 1 3/4" galvanized grating | 5,000 | sq ft | 5.65 | 28,250 |
| | Spiral stairs (Gr. 12.0 to Gr. -43.5) | 30 | sets | 3,000 | 90,000 |
| | Pressed metal stairs (east service bay Gr. 27.0 to upper floors and roof), incl. rail and inserts | 152 | l.f.tr. | 23.00 | 3,500 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 321 | Power Plant Structures and Improvements (Cont'd) | | | | |
| .161 | Structural Steel and Miscellaneous Iron (Cont'd) | | | | |
| | Pipe Railing | | | | |
| | Wall rail (single) | 700 | lin ft | $3.50 | $2,450 |
| | Hand rail (double) | 600 | lin ft | 5.50 | 3,300 |
| | Platform framing and supports for servicing bridge cranes | Allowance | | | 5,000 |
| | Additional exits from service bays, ships ladders, incl. exit bulkheads | 4 | each | 1,500 | 6,000 |
| | Ladders with cages in sumps | 4 | each | 500.00 | 2,000 |
| | Miscellaneous ladders | Allowance | | | 10,000 |
| | Steel door bucks in partitions | 7 | tons | 475.00 | 3,325 |
| | Abrasive nosing concrete stairs | 2,000 | lin ft | 1.50 | 3,000 |
| | Miscellaneous embedded steel | Allowance | | | 12,000 |
| | Manhole frames and covers | | | | 500 |
| | Total, Acct. 321.161 | | | | $432,070 |
| .162 | Walls | | | | |
| .1624 | Concrete - Exterior Walls | | | | |
| .16241 | Forms | 25,200 | sq ft | 1.75 | $44,100 |
| .16242 | Reinforcing steel | 18 | tons | 380.00 | 6,840 |
| .16243 | Concrete | | | | |
| .162431 | Aggregate | 325 | cu yd | 27.20 | 8,840 |
| .162432 | Cement | 413 | bbl | 7.20 | 2,975 |
| .16246 | Rubbing | 17,000 | sq ft | .15 | 2,550 |
| | Total, Acct. 321.162 | | | | $65,305 |
| .163 | Roof, Incl. Roofing and Sheet Metalwork | | | | |
| .1632 | Precast Concrete Slabs | | | | |
| .16321 | Flexicore roof slabs | 7,800 | sq ft | 1.50 | $11,700 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 321 | Power Plant Structures and Improvements (Cont'd) | | | | |
| .1637 | Roofing, Flashing, Sheet Metalwork and Insulation | | | | |
| | Offices and Visitors' Gallery | | | | |
| | Insulation | 7,800 | sq ft | $.30 | $2,340 |
| | Roofing | 7,800 | sq ft | .40 | 3,120 |
| | Membrane water-proofing | 245,000 | sq ft | .35 | 85,750 |
| | Flashing - 16 oz copper | 1,200 | sq ft | 2.00 | 2,400 |
| | Total, Acct. 321.1637 | | | | $93,610 |
| .1638 | Traffic Paving, Incl. Wire Mesh Reinforcing | | | | |
| | Wire mesh | 245,000 | sq ft | .10 | $24,500 |
| | Paving, 6" | 4,600 | cu yd | 30.00 | 138,000 |
| | Cement | 5,790 | bbl | 7.20 | 41,690 |
| | Total, Acct. 321.1638 | | | | $204,190 |
| | Total, Acct. 321.163 | | | | $309,500 |
| .164 | Interior Partitions, Trim and Finish | | | | |
| .1641 | Ceilings | | | | |
| | Acoustic tile (attached) | 4,900 | sq ft | .74 | $3,635 |
| | Vermiculite Plaster | | | | |
| | Office Buildings | | | | |
| | Attached to underside roof slabs | 650 | sq yd | 3.85 | 2,500 |
| | Suspended ceilings | 400 | sq yd | 9.50 | 3,800 |
| | Total, Acct. 321.1641 | | | | $9,935 |
| .1642 | Carpentry and Millwork | | | None | |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 321 | Power Plant Structures and Improvements (Cont'd) | | | | |
| .1644 | Floor Slabs, Incl. Columns and Beams | | | | |
| .16441 | Concrete - Supported Slabs | | | | |
| | Forms | 7,200 | sq ft | $2.25 | $16,200 |
| .16442 | Reinforcing steel | 12 | tons | 390.00 | 4,680 |
| .164431 | Aggregate | 250 | cu yd | 30.00 | 7,500 |
| .164432 | Cement | 352 | bbl | 7.20 | 2,535 |
| | Total, Acct. 321.1644 | | | | $30,915 |
| .1645 | Interior Partitions | | | | |
| | Masonry Walls | | | | |
| | 8" concrete block | 13,600 | sq ft | 1.35 | $18,360 |
| | 8" glazed tile (1f) | 3,800 | sq ft | 4.00 | 15,200 |
| | 8" glazed tile (2f) | 600 | sq ft | 4.50 | 2,700 |
| | 2" glazed tile (2f) | 3,000 | sq ft | 2.60 | 7,800 |
| | 4" glazed tile (2f) | 8,900 | sq ft | 3.30 | 29,370 |
| | Shower stalls | 2 | each | 500.00 | 1,000 |
| | Metal lath and vermiculite plaster | 9,400 | sq ft | 1.75 | 16,450 |
| | Vermiculite plaster on masonry | 4,600 | sq ft | 1.50 | 6,900 |
| | Fixed metal partitions | 2,400 | sq ft | 2.75 | 6,600 |
| | Moveable metal partitions | 1,200 | sq ft | 3.00 | 3,600 |
| | Toilet stalls | 22 | each | 150.00 | 3,300 |
| | Wire grille partitions | 8,300 | sq ft | 2.50 | 20,750 |
| | Total, Acct. 321.1645 | | | | $132,030 |
| .1646 | Floor Finish | | | | |
| | Granolithic Finish | | | | |
| | Powerhouse | 175,000 | sq ft) | | |
| | Service bays | 32,600 | sq ft) | .60 | $124,560 |
| | Stair finish | 2,000 | l.f.tr. | .60 | 1,200 |
| | Monolithic Finish | | | | |
| | Under vinyl tile floors | 13,600 | sq ft) | | |
| | Under ceramic tile | 3,450 | sq ft) | .30 | 5,115 |
| | Ceramic tile | 3,450 | sq ft | 2.25± | 7,650 |
| | Vinyl tile | 13,600 | sq ft | 1.50 | 20,400 |
| | Floor Finish Battery rooms | 2,450 | sq ft | .80 | 1,960 |
| | Total, Acct. 321.1646 | | | | $160,885 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 321 | Power Plant Structures and Improvements (Cont'd) | | | | |
| .1647 | Painting, structures and service equipment | | | | $400,000 |
| .1648 | Temporary protection | Allowance | | | 150,000 |
| | Total, Acct. 321.164 | | | | $883,765 |
| .165 | Doors and Windows, Incl. Hardware, Glass and Glazing | | | | |
| .1651 | Industrial steel doors and frames | 1,100 | sq ft | $8.00 | $8,800 |
| | Stainless steel door and frame | | | | 750 |
| | Total, Acct. 321.1651 | | | | $9,550 |
| .1652 | Sash, Incl. Hardware, Glass and Glazing | | | | |
| | Aluminum Projected Windows | | | | |
| | Powerhouse | 6,500 | sq ft | 3.00 | $19,500 |
| | Service bays | 1,600 | sq ft | 3.00 | 4,800 |
| | Vision panels, incl. frames | 710 | sq ft | 6.00 | 4,260 |
| | Total, Acct. 321.1652 | | | | $28,560 |
| | Total, Acct. 321.165 | | | | $38,110 |
| .166 | Plumbing | | | | |
| | Roof and deck drains (office areas) | 4 | each | 700.00 | $2,800 |
| | Station drainage system | | | | 52,100 |
| | Fixtures, incl. hot, cold, waste and vent piping | | | | 42,800 |
| | Total, Acct. 321.166 | | | | $97,700 |
| .167 | Heating and Ventilating | | | | |
| | Heating | | | | |
| | Powerhouse | | | | $282,100 |
| | Service bays | | | | 34,900 |
| | | | | | 317,000 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 321 | Power Plant Structures and Improvements (Cont'd) | | | | |
| .167 | Heating and Ventilating (Cont'd) | | | | |
| | Ventilating | | | | |
| | Powerhouse | | | | $26,350 |
| | Service bays, incl. office areas | | | | 36,250 |
| | | | | | 62,600 |
| | Total, Acct. 321.167 | | | | $379,600 |
| .168 | Lighting | | | | |
| | Lighting System - Powerhouse | | | | |
| | Fixtures, conduit, wire, switches, outlets and panel boards | 30 | units | $9,750 | $292,500 |
| | Lighting System - Service Area | | | | |
| | Incandescent recessed fixtures and flood-lights on deck, El. 27.0 and fixtures, conduit, wire, switches, outlets and panel boards for fluorescent lighting of erection bays, shop areas, utility rooms and office areas | | | | 81,300 |
| | Total, Acct. 321.168 | | | | $373,800 |
| .169 | Miscellaneous | | | | |
| | Elevator, incl. machinery room | | | | $22,000 |
| | Stair kiosk roof, east office building | | lot | | 1,500 |
| | Total, Acct. 321.169 | | | | $23,500 |
| | Total, Acct. 321.16 | | | | $2,603,350 |
| | Total, Acct. 321 | | | | $48,957,000 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 322 | Reservoir, Dams and Waterways | | | | |
| .6 | Integral Powerhouse and Intake Dam Structural Work | | | | |
| .61 | Intake Gates and Appurtenances | | | | |
| .611 | Gates and Guides | | | | |
| .6111 | Gates (3 sets) | 270 | tons | $1,200 | $324,000 |
| .6112 | Guides and embedded steel | 1,125 | tons | 950.00 | 1,068,750 |
| .6113 | Dogging devices | 15 | tons | 1,100 | 16,500 |
| | Total, Acct. 322.611 | | | | $1,409,250 |
| .612 | Trash Racks and Stop Logs | | | | |
| .6121 | Trash Racks | | | | |
| | Racks | 1,575 | tons | 825.00± | $1,299,600 |
| | Supports and embedded steel | 225 | tons | 700.00 | 157,500 |
| | 1 set of spare racks | 17 1/2 | tons | 825.00± | 14,450 |
| | | | | | 1,471,550 |
| .6122 | Stop logs, 1 set (steel) | 120 | tons | 650.00 | 78,000 |
| | Total, Acct. 322.612 | | | | $1,549,550 |
| .613 | Hoists and Gantry Cranes | | | | |
| | 30-ton intake gantry cranes, incl. lifting beam and 10-ton capacity auxiliary jib hoist, self-propelled | 2 | each | 73,000 | $146,000 |
| .615 | Intake Grating Covers and Framing | | | | |
| | Framing angles | 22 | tons | 600.00 | 13,200 |
| | Grating, 3" | 8,000 | sq ft | 9.75 | 78,000 |
| | | | | | 91,200 |
| .619 | Painting | | | | 68,000 |
| | Total, Acct. 322.6 | | | | $3,264,000 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 322 | Reservoir, Dams and Waterways (Cont'd) | | | | |
| .9 | Tailrace | | | | |
| .93 | Gates, Hoists and Appurtenances | | | | |
| .931 | Gates | | | | |
| .9311 | Draft tube (3 sets) | 270 | tons | $1,200 | $324,000 |
| .9312 | Guides and embedded steel | 855 | tons | 950.00 | 812,250 |
| .9313 | Dogging devices | 15 | tons | 1,100 | 16,500 |
| | Total, Acct. 322.931 | | | | $1,152,750 |
| .935 | Draft Tube Grating Covers and Frames | | | | |
| | Frames | 15 | tons | 600.00 | $9,000 |
| | Grating, 1 3/4" | 8,000 | sq ft | 5.65 | 45,200 |
| | | | | | 54,200 |
| .939 | Painting | | | | 24,050 |
| | Total, Acct. 322.9 | | | | $1,231,000 |
| | Total, Acct. 322 | | | | $4,495,000 |
| 323 | Water Wheels, Turbines and Generators | | | | |
| .1 | Turbines, Governors, Pumps and Piping | | | | |
| .11 | Turbines and governors, fixed blade, propeller type | 30 | units | 1,153,000+ | $34,600,000 |
| | Alignment of turbine and generator shaft assemblies and furnishing and fitting coupling bolts | 30 | units | | Included |
| | Services of erecting engineers | | | | Included |
| .12 | Lubricating oil system, incl. lubricants | | | | 282,000 |
| | Total, Acct. 323.1 | | | | $34,882,000 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 323 | Water Wheels, Turbines and Generators (Cont'd) | | | | |
| .2 | Generators, Exciters and Appurtenances | | | | |
| .21 | Generators and Direct Connected Exciters | | | | |
| | Hydraulic turbine driven | 30 | units | $1,000,000 | $30,000,000 |
| | Direct connected exciters and pilot exciters | | | Included Above | |
| | Generator cooling system and bearing lubricating system | | | Included Above | |
| | Spare parts | | | Included Above | |
| .22 | Generator Cooling Systems | | | | |
| | Heat exchangers and appurtenances | 13 | each | 41,865 | 544,200 |
| .24 | Generator Fire Protection System | | | | |
| | $CO_2$ equipment | | | | 167,800 |
| | Total, Acct. 323.2 | | | | $30,712,000 |
| .3 | Turbine and generator tests | 30 | each | 5,000 | $150,000 |
| | Painting turbines | | | | 225,000 |
| | Total, Acct. 323 | | | | $65,969,000 |
| 324 | Accessory Electric Equipment | | | | |
| .1 | Connections, Supports and Structures | | | | |
| .12 | Conductors and Insulators | | | | |
| .121 | Insulators and Bushings | | | | |
| .1211 | 15 kv bus supports complete with inserts, 9 per unit | 270 | each | 90.00 | $24,300 |
| .1212 | Transite or equal insulation board | 1,200 | sq ft | 7.50 | 9,000 |
| .122 | Bare Copper and Tube Work | | | | |
| .1221 | Bare copper bar, main and neutral connections | 5,000 | lb | 3.70 | 18,500 |
| .1222 | Segregated phase leads, 15 kv, 2,000 amp for bus ties | 140 | ft | 590.00 | 82,600 |
| .1223 | Isolated phase leads, 15 kv, 4,000 amp with floor bushings for transformer connections (3 phase) | 88 | ft | 1,390 | 122,320 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 324 | Accessory Electric Equipment (Cont'd) | | | | |
| .123 | Power Cable and Accessories | | | | |
| .1231 | 15 Kv Cable, O.B. Insulation | | | | |
| | Generator leads, neutral bus and S.S. transformer primary | 66,000 | lb | $3.70 | $244,200 |
| .1232 | 15 kv cable P.L. for 13.8 kv feeders | 19,000 | lb | 2.20 | 41,800 |
| .1233 | 600 v power cable (powerhouse) | 72,750 | lb | 2.95 | 214,600 |
| | 600 v power cable (service bays) | 13,000 | lb | 2.95 | 38,350 |
| .1234 | 600 v cable bus in aluminum enclosure, 1,000 amp | 1,800 | ft | 37.25± | 67,000 |
| | 600 v cable bus in aluminum enclosure, 600 amp | 5,000 | ft | 30.00 | 150,000 |
| .124 | Control Wiring and Accessories | | | | |
| .1241 | 600 v control wire (powerhouse) | 30,000 | lb | 4.45 | 133,500 |
| | 600 v control wire (service bays) | 2,000 | lb | 4.45 | 8,900 |
| .1242 | Supervisory, pilot and telephone wire (powerhouse) | 3,500 | lb | 5.15± | 18,000 |
| | Supervisory, pilot and telephone wire (service bays) | 100 | lb | 5.15 | 520 |
| .125 | Grounding System | | | | |
| .1251 | Main ground bus, 1/4" x 4" aluminum, with inserts and bolts (powerhouse) | 2,500 | ft | 5.90 | 14,800 |
| | Main ground bus, 1/4" x 4" aluminum, with inserts and bolts (service bays) | 300 | lin ft | 5.90 | 1,770 |
| .1252 | Copper conductors and plates | 25,000 | lb | 2.95 | 73,800 |
| .1253 | Connectors and fittings | 400 | each | 14.75 | 5,900 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 324 | Accessory Electric Equipment (Cont'd) | | | | |
| .126 | Pipe and Steel Supports | | | | |
| | Miscellaneous structural steel galvanized 2,000 lb per unit (powerhouse) | 30 | tons | $1,030 | $30,900 |
| | Miscellaneous structural steel galvanized (service bays) | 2 | tons | 1,036 | 2,060 |
| | Total, Acct. 324.12 | | | | $1,302,820 |
| .13 | Conduits | | | | |
| .132 | Steel conduits and fittings (powerhouse) | 200,000 | lb | 3.30 | $660,000 |
| | Steel conduits and fittings (service bays) | 20,000 | lb | 3.30 | 66,000 |
| .133 | Transite conduit and supports, 13.8 kv feeders | 3,000 | ft | 2.95± | 8,900 |
| .134 | Cable trays, alum, with galvanized steel supports | 12,000 | ft | 22.00 | 264,000 |
| .135 | Aluminum conduit, 4" for 15 kv leads | 13,000 | ft | 6.80 | 88,400 |
| .136 | 440 v power receptacles (10 per unit) | 300 | each | 75.00 | 22,500 |
| | 440 v power receptacles (service bays) | 12 | each | 75.00 | 900 |
| | Total, Acct. 324.13 | | | | $1,110,700 |
| | Total, Acct. 324.1 | | | | $2,413,520 |
| .2 | Switchgear and Control Equipment | | | | |
| .22 | Transformers | | | | |
| .222 | Lighting Transformers | | | | |
| | Powerhouse | | | | |
| | 45 kva, 3 phase, 480-208/120 v dry type with taps | 30 | each | 1,400 | $42,000 |
| | Service Bays | | | | |
| | 45 kva, 3 phase, 480-208/120 v dry type with taps | 4 | each | 1,400 | 5,600 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 324 | Accessory Electric Equipment (Cont'd) | | | | |
| .223 | Generator voltage regulators, rheostatic type | 30 | each | $7,370 | $221,100 |
| | Induction regulators, 43.2 kva ±10% for lighting (powerhouse) | 4 | each | 5,160± | 20,650 |
| | Induction regulators, 10.8 kva ±10% for lighting (service bays) | 2 | each | 3,100 | 6,200 |
| .224 | Potential transformers in cubicles, 6" each | 30 | sets | 7,370 | 221,100 |
| | Current transformers, 600 amp | 120 | each | 445.00 | 53,400 |
| | Current transformers, 4,000 amp | 2 | each | 375.00 | 750 |
| | Current transformers, 5,000 amp | 2 | each | 450.00 | 900 |
| | Total, Acct. 324.22 | | | | $571,700 |
| .24 | Surge Protection (Turbine Generator) | | | | |
| .241 | Generator Surge Protection Cubicle with 3LA and 6 capacitors | 30 | each | 4,425 | $132,750 |
| .244 | Neutral Grounding Resistor 10 ohm, 1 min | 4 | each | 9,600 | 38,400 |
| | Total, Acct. 324.24 | | | | $171,150 |
| .25 | Switchboards and Appurtenances | | | | |
| .251 | Generator Control and Relay Board, Duplex Type, For 8 Generators 1 feeder, 1 station service feeder and main transformer | 2 | each | 107,600 | $215,200 |
| | Generator Control and Relay Board, Duplex Type for 7 Generators 1 feeder, 1 station service feeder and main transformer | 2 | each | 96,850 | 193,700 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 324 | Accessory Electric Equipment (Cont'd) | | | | |
| .25 | Switchboards and Appurtenances (Cont'd) | | | | |
| | Supervisory control equipment for 30 generators, incl. master and remote panels, automatic synchronizing equipment | | lot | | $280,000 |
| | Direct current control and distribution boards | 4 | each | 5,900 | 23,600 |
| | Water level indicator recorder | 1 | each | | 1,500 |
| | Oscillograph | 4 | each | 12,500 | 50,000 |
| | Total, Acct. 324.25 | | | | $764,000 |
| .26 | Auxiliary Power Equipment | | | | |
| .261 | Battery charging motor generator sets, 7 1/2 kw | 4 | each | 2,500 | $10,000 |
| .262 | Control storage battery, nickel cadmium, 125 v, with rack | 4 | each | 8,850 | 35,400 |
| | Total, Acct. 324.26 | | | | $45,400 |
| | Total, Acct. 324.2 | | | | $1,552,250 |
| .3 | Cubicles and Appurtenances | | | | |
| .31 | 15 Kv Metalclad Switchgear, With 1,200 Amp, 750 Mva Air Circuit Breakers, Drawout Type | | | | |
| | 8 unit groups (powerhouse) | 2 | each | 207,850 | $415,700 |
| | 7 unit groups (powerhouse) | 2 | each | 190,900 | 381,800 |
| | 15 kv metalclad switchgear with 1,200 amp, 750 mva, air circuit breakers, drawout type (service bays) | 4 | each | 19,900 | 79,600 |
| | Power distribution cabinet, 8 circuits, 440 v, 3 phase (service bays) | 2 | each | 1,035 | 2,070 |
| | Total, Acct. 324.31 | | | | $879,170 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 324 | Accessory Electric Equipment (Cont'd) | | | | |
| .32 | Station service unit substations, each with 1 - 900 kva dry type transformer, 13,200-480 v secondary air circuit breaker, 9 feeder air circuit breakers and 2 tie air circuit breakers (powerhouse) | 4 | each | $61,900 | $247,600 |
| | Spare transformer unit, 900 kva | 1 | each | 17,700 | 17,700 |
| | Station service substation each with 1 - 900 kva dry type transformer 13,200-480 v secondary, 1,200 amp air circuit breaker and 6 feeder air circuit breakers | 2 | each | 42,750 | 85,500 |
| | Total, Acct. 324.32 | | | | $350,800 |
| .33 | Substation switchgear cubicle with exciter field air circuit breaker and space for exciter field rheostat | 30 | each | 2,650 | $79,500 |
| .34 | Lighting bus supply air circuit breakers, 400 amp complete in steel cabinet | 4 | each | 1,050 | 4,200 |
| .35 | Motor control centers with combination air circuit breakers and magnetic starters | 30 | each | 8,100 | 243,000 |
| | Reversing contactors for lighting transformers | 30 | each | 590.00 | 17,700 |
| | Push button control switches and interlocks for motors | 600 | each | 60.00 | 36,000 |
| | Motor control centers with combination air circuit breakers and magnetic starters (service bays) | 6 | each | 5,160 | 30,960 |
| | Push button control switches and interlocks (service bays) | 100 | each | 60.00 | 6,000 |
| | Total, Acct. 324.35 | | | | $333,660 |

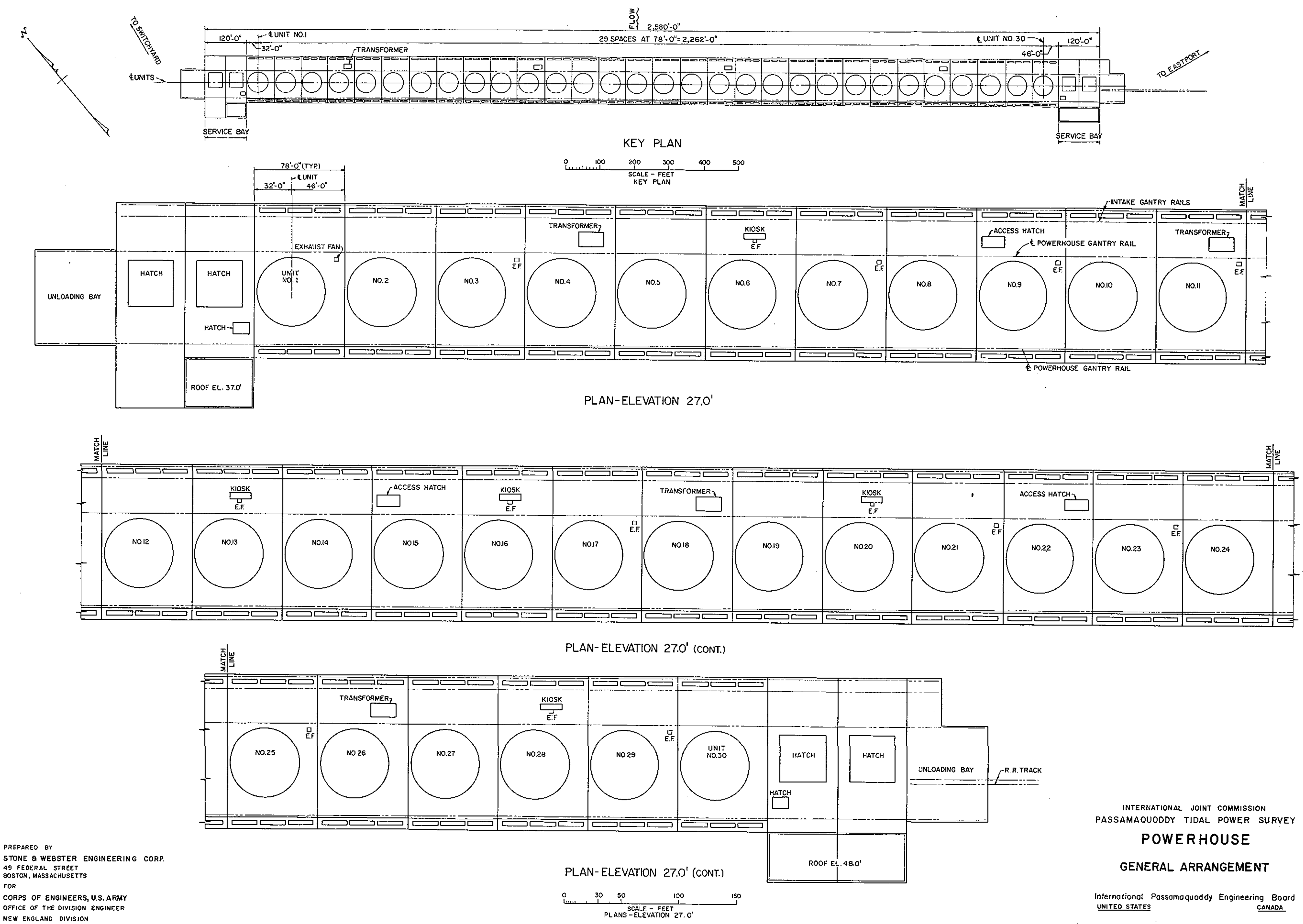
| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 324 | Accessory Electric Equipment (Cont'd) | | | | |
| .36 | Generator Neutral Switch-gear | | | | |
| | Air circuit breaker housings, only | 30 | each | $3,830 | $114,900 |
| | Air circuit breakers, drawout type | 8 | each | 10,625 | 85,000 |
| | Total, Acct. 324.36 | | | | $199,900 |
| | Total, Acct. 324.3 | | | | $1,847,230 |
| .4 | Testing equipment | Allowance | | | $3,000 |
| | Total, Acct. 324 | | | | $5,816,000 |
| 325 | Miscellaneous Power Plant Equipment | | | | |
| .1 | Auxiliary Equipment | | | | |
| .11 | Unwatering and Low Level Drainage | | | | |
| .111 | Unwatering pump, 5,000 gpm, 100 TDH, vertical turbine type, bronze casting, instruments and controls | 2 | each | 47,500 | $95,000 |
| .112 | Piping | | | | |
| | 24" cast iron header | 2,350 | lin ft | 25.00 | 58,700 |
| | 20" cast iron riser to mud valve | 150 | lin ft | 22.00 | 3,300 |
| | 20" mud valves | 30 | each | 500.00 | 15,000 |
| | Extension stems | 30 | each | 75.00 | 2,250 |
| | Floor stand | 30 | each | 150.00 | 4,500 |
| | Packing boxes | 30 | each | 50.00 | 1,500 |
| | Pipe sleeves for stems | 30 | each | 100.00 | 3,000 |
| | 18" cast iron pump discharge | 150 | lin ft | 20.00 | 3,000 |
| | 18" cast iron gate valve | 2 | each | 1,600 | 3,200 |
| | 18" cast iron check valve | 2 | each | 1,900 | 3,800 |
| | 20" cast iron drain line (scroll case) | | | | 46,000 |
| | 20" wall castings - water stops (scroll case) | 60 | each | 290.00 | 17,400 |
| | 20" cast iron drain box, coated (scroll case) | 30 | each | 150.00 | 4,500 |
| | 20" gate valves (scroll case) | 30 | each | 2,300 | 69,000 |
| | Total, Acct. 325.112 | | | | $235,150 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 325 | Miscellaneous Power Plant Equipment (Cont'd) | | | | |
| .115 | Cathodic protection equipment, incl. rectifiers, leads and controls | 30 | sets | $5,900 | $177,000 |
| | Total, Acct. 325.11 | | | | $507,150 |
| .12 | Gages, Indicating and Recording Devices | | | | |
| .124 | Water level recording equipment | | | | $15,000 |
| .125 | Miscellaneous gages and flowmeters | | | | 25,000 |
| | Total, Acct. 325.12 | | | | $40,000 |
| .14 | Low pressure system (100 psi) | | | | $94,900 |
| | High pressure system (300 psi) | | | | 68,500 |
| | Total, Acct. 325.14 | | | | $163,400 |
| .15 | Deck washdown and station fire protection system | | | | $8,900 |
| .16 | Cranes | | | | |
| .161 | Powerhouse Gantry Cranes 220 ton capacity | 2 | each | $730,000 | 1,460,000 |
| .162 | Other Hoist Equipment | | | | |
| | 10-ton bridge cranes in service bays | 2 | each | 18,900 | 37,800 |
| | 5-ton bridge cranes in maintenance shops | 2 | each | 16,300 | 32,600 |
| | Total, Acct. 325.16 | | | | $1,530,400 |
| .19 | Miscellaneous auxiliary equipment, incl. lockers, benches and tables | | | | $50,000 |
| | Total, Acct. 325.1 | | | | $2,299,850 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 325 | Miscellaneous Power Plant Equipment (Cont'd) | | | | |
| .2 | General Station Equipment | | | | |
| .21 | Shop equipment | | | | $68,300 |
| .221 | Office equipment | | lot | | 5,000 |
| .229 | Miscellaneous utility equipment | | lot | | 7,700 |
| .23 | Yard Equipment | | | | |
| | Snow removal machines | 2 | each | 30,000 | 60,000 |
| | Total, Acct. 325.2 | | | | $141,000 |
| .3 | Communication System Equipment | | | | |
| .311 | 2 Trunks and 100 Lines (PABX) With Code Call Feature | | | | |
| | Powerhouse (25 stations) | | lot | | $29,500 |
| | Service area (additional stations) | 16 | each | 60.00± | 950 |
| | Steel conduit | 3,000 | lb | 3.30 | 9,900 |
| | Wire (TW) and tensioned blocks | | lot | | 11,800 |
| | Total, Acct. 325.3 | | | | $52,150 |
| | Total, Acct. 325 | | | | $2,493,000 |
| 343 | Substation and Switching Station Equipment - Transmission Plant | | | | |
| .1 | Connections, Supports and Structures | | | | |
| .11 | Steel arbor for lightning arrester supports | 4 | each | 5,750 | $23,000 |
| .12 | Conductors and Insulators | | | | |
| .121 | Connections to lightning arresters | 4 | lots | 885.00± | 3,500 |
| | Total, Acct. 343.1 | | | | $26,500 |
| .2 | Switchgear and Control Equipment | | | | |
| .21 | Transformers | | | | |
| .211 | Main power transformer, 90,000 kva, 3 phase, FOA, 13.2-230 kv | 2 | each | 633,850 | $1,267,700 |
| | Main power transformer, 90,000 kva, 3 phase, FOA, 13.2-138 kv | 2 | each | 398,000 | 796,000 |

| Acct. No. | Description | Quantity | Unit | Rate | Total |
|---|---|---|---|---|---|
| 343 | Substation and Switching Station Equipment - Transmission Plant (Cont'd) | | | | |
| .23 | Surge Protection | | | | |
| .231 | Lightning arresters, 195 kv for 230 kv transformers, inverted suspension mounting | 6 | each | $3,980± | $23,900 |
| | Lightning arresters, 121 kv for 138 kv transformers, inverted suspension mounting | 6 | each | 2,500 | 15,000 |
| | Total, Acct. 343.2 | | | | $2,102,600 |
| .4 | Auxiliary Equipment | | | | |
| .43 | Oil storage systems, incl. tank trailers | | | | $46,400 |
| .48 | Transformer Fire Protection System | | | | |
| | Automatic spray system | 4 | each | 12,000 | 48,000 |
| | Annunciation system | 5 | each | 1,000 | 5,000 |
| | 12" main header | 2,200 | lin ft | 17.75 | 39,000 |
| | Hangers and supports | Allowance | | | 2,500 |
| | Total, Acct. 343.48 | | | | $94,500 |
| | Total, Acct. 343.4 | | | | $140,900 |
| .6 | Communication and supervisory equipment for switchyard in station | | | | Not Included |
| | Total, Acct. 343 | | | | $2,270,000 |

PLATE I

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BOSTON, MASSACHUSETTS
FOR
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASSACHUSETTS

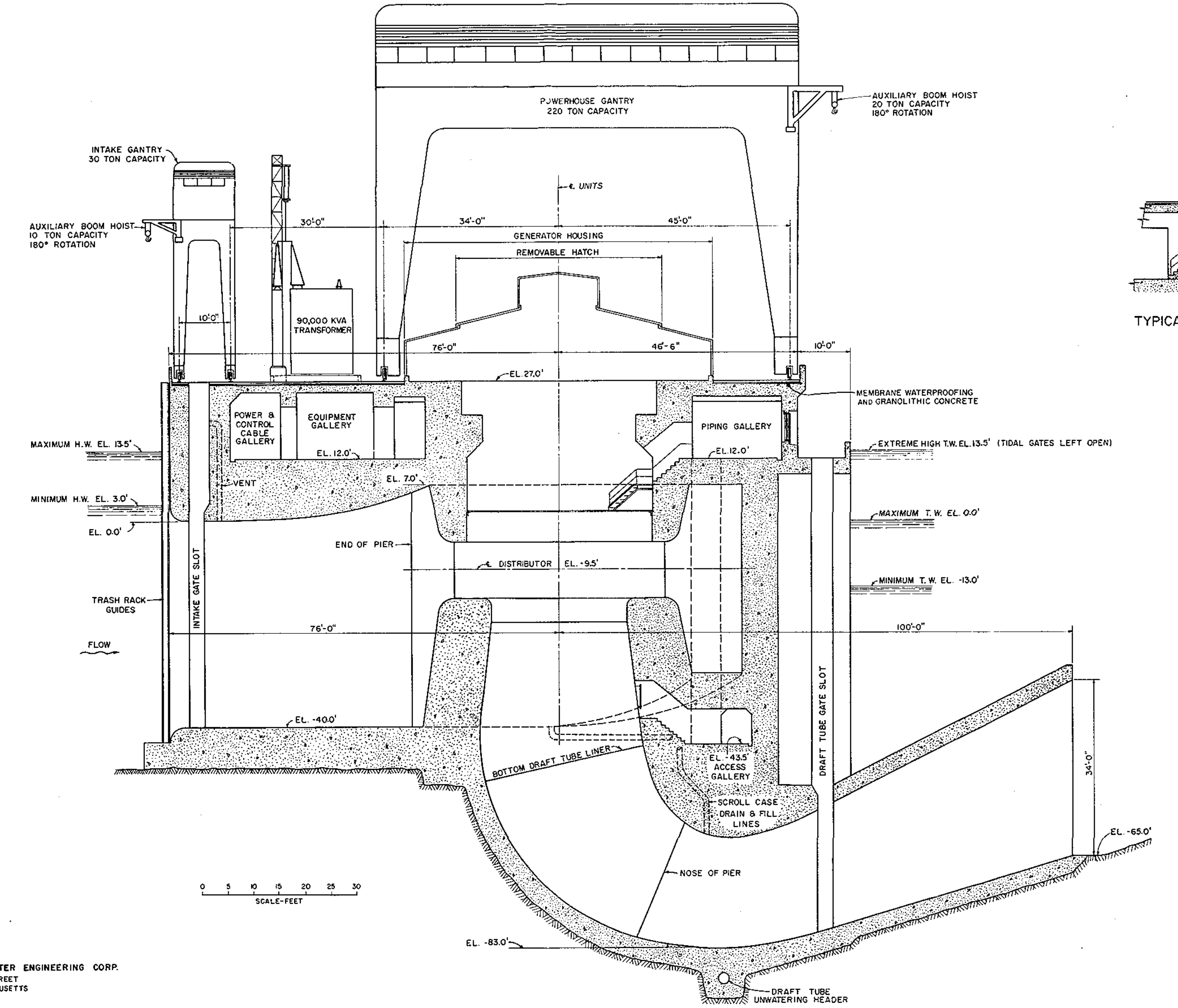
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

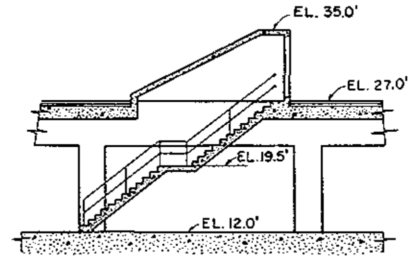
POWERHOUSE

GENERAL ARRANGEMENT

International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958 Dwg. No. TP7-001




TYPICAL SECTION THRU KIOSK

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INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

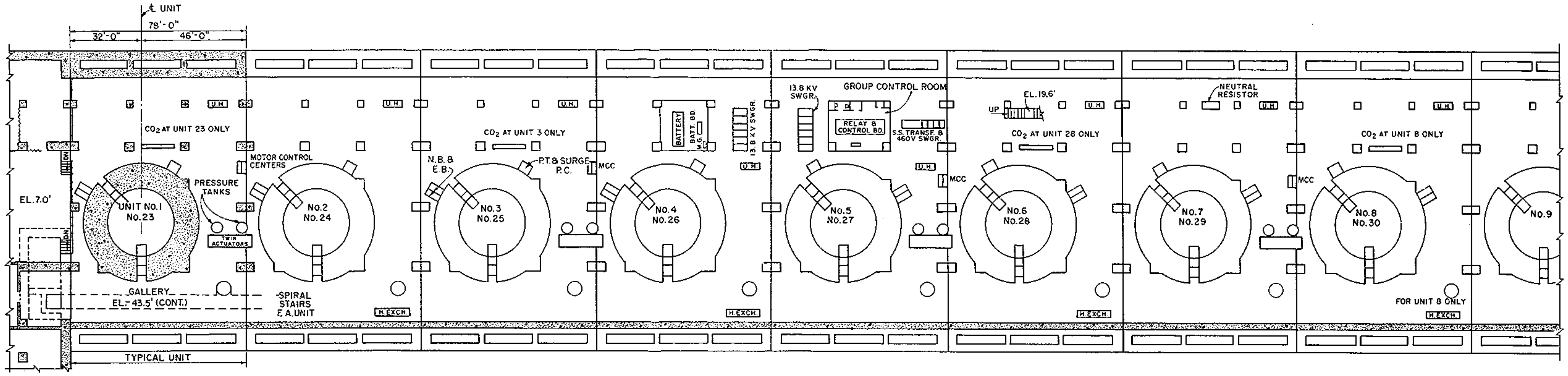
**POWERHOUSE**

TYPICAL CROSS SECTION

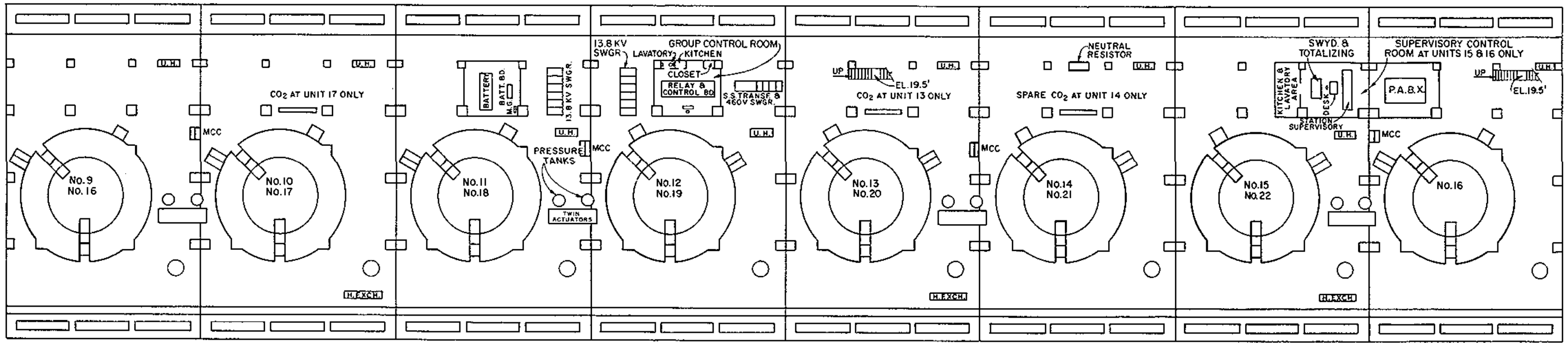
International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958

Dwg. No. TP7-002

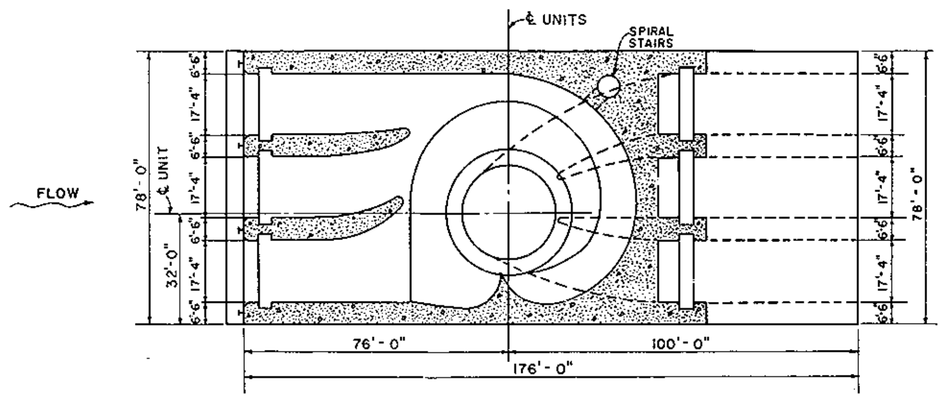



PLAN - ELEVATION 12.0'
TYPICAL 8 UNIT GROUP (UNITS 1 TO 8)
UNITS 23 TO 30 SIMILAR




PLAN - ELEVATION 12.0'
TYPICAL 7 UNIT GROUP (UNITS 9 TO 15)
UNITS 16 TO 22 SIMILAR

0 20 40 60 80 100
SCALE - FEET




PLAN ON ℄ DISTRIBUTOR

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BOSTON, MASSACHUSETTS

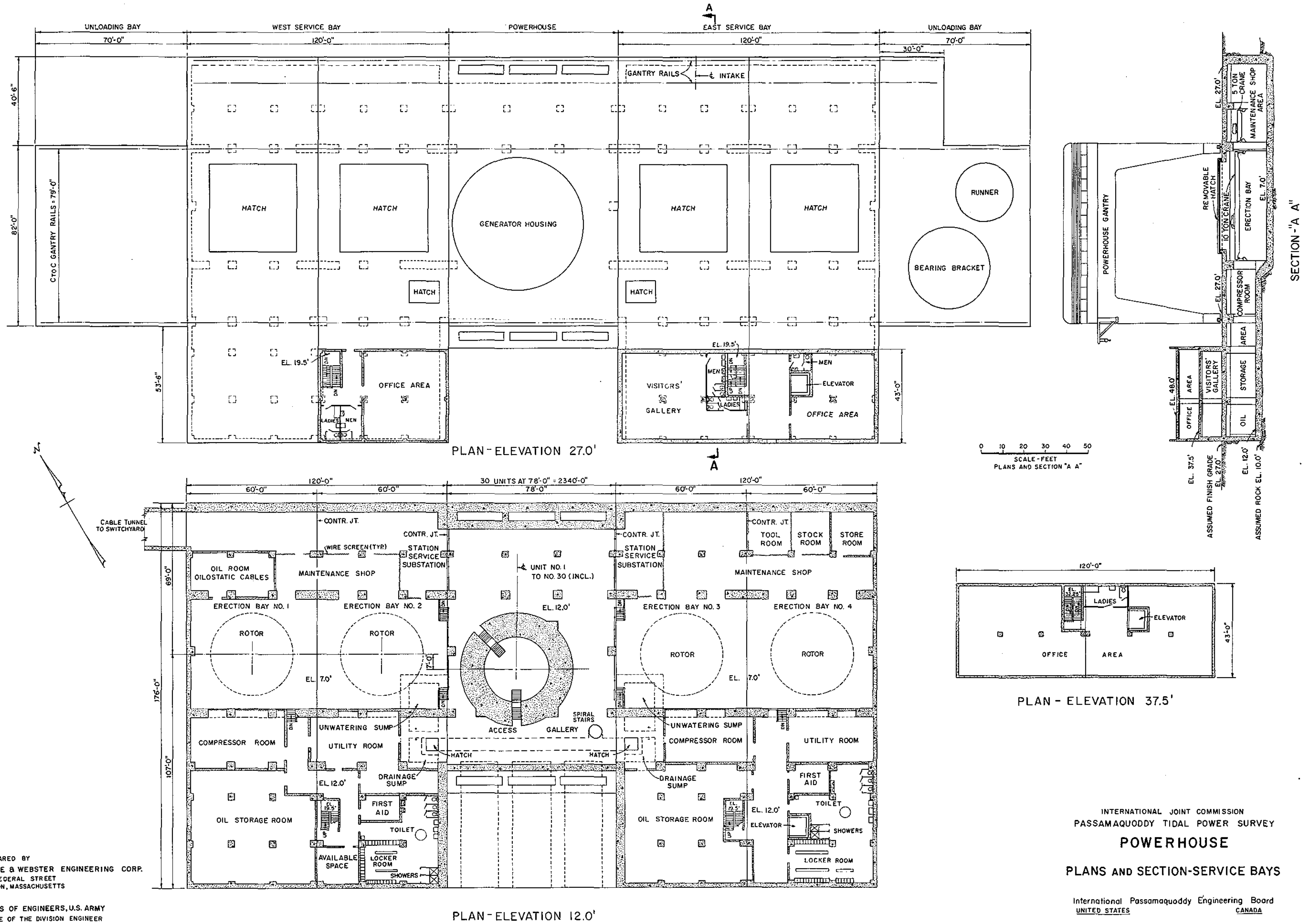
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

**POWERHOUSE**

**PLAN-OPERATING FLOOR**

International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958
Dwg. No. TP7-003

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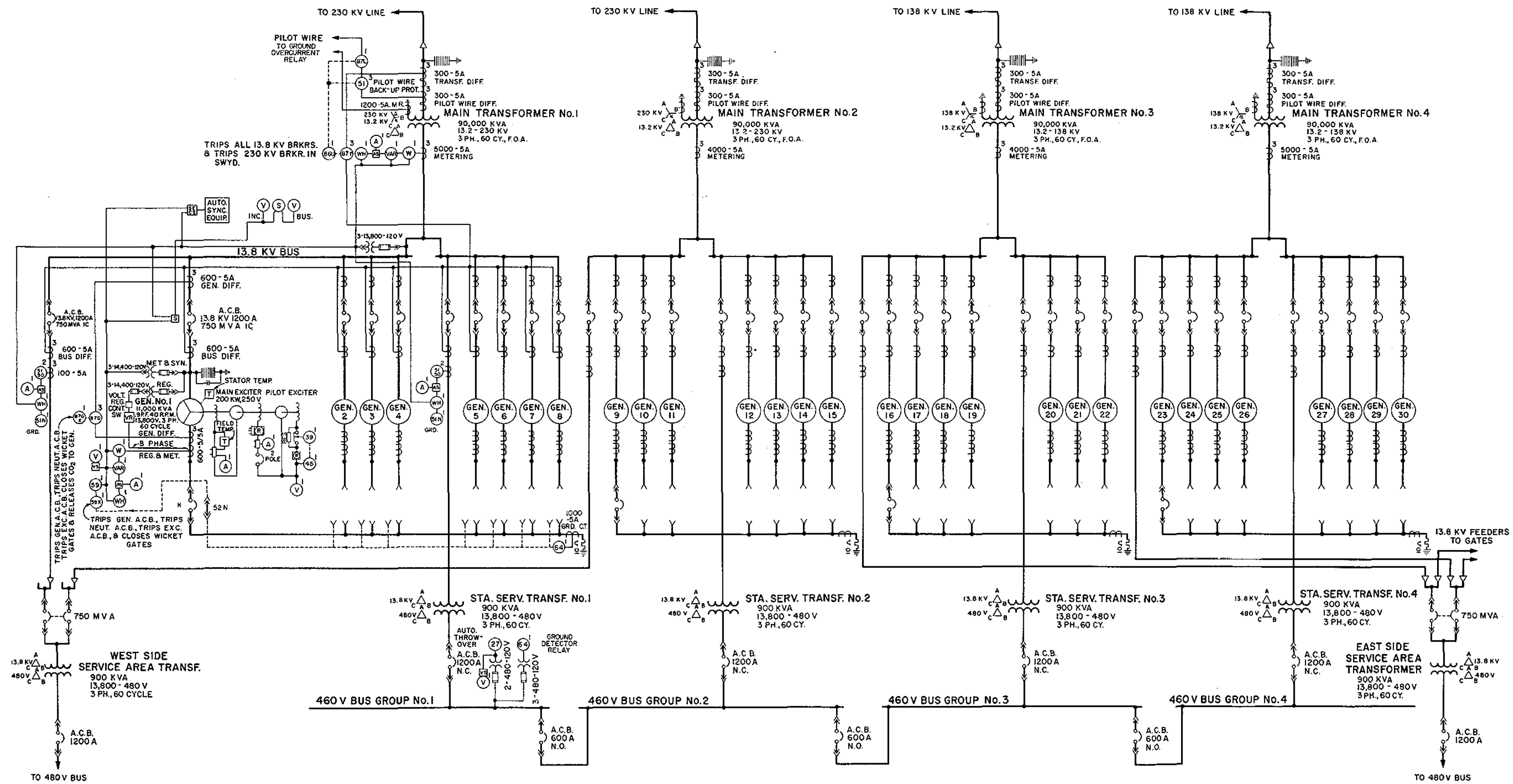
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

**POWERHOUSE**

PLANS AND SECTION-SERVICE BAYS

International Passamaquoddy Engineering Board
UNITED STATES — CANADA

Date: JUNE 30, 1958 — Dwg. No. TP7-004




LEGEND:

- AIR CIRCUIT BREAKER - ELECTRICALLY OPERATED
- DISCONNECT DEVICE
- CURRENT TRANSFORMER - NUMERAL INDICATES QUANTITY
- CURRENT TRANSFORMER - BUSHING TYPE, MULTI - RATIO
- POTENTIAL TRANSFORMER
- FUSE
- LIGHTNING ARRESTER
- SHUNT
- RHEOSTAT - MANUALLY OPERATED
- RHEOSTAT - ELECTRICALLY OPERATED
- POTHEAD
- RESISTOR

- AS: SWITCH; AS - AMMETER, S - SYNCHRONIZING, VS - VOLTMETER
- T: RECORDING METER; T - TEMPERATURE
- VR: VOLTAGE RECORDER
- AUTOMATIC SYNCHRONIZING EQUIPMENT CONTROL SWITCH AND SELECTOR RELAYS
- A: INDICATING METER, A - AMMETER, V - VOLTMETER, VAR - VARMETER, W - WATTMETER, WH - WATTHOUR METER, S - SYNCHROSCOPE
- 27: RELAY OR OPERATING COIL, NUMERAL INDICATES DEVICE NUMBER
- W: INDICATING LAMP, W - WHITE
- MR: MULTI RATIO

DEVICE NUMBERS:

- 27 AC UNDERVOLTAGE RELAY
- 45 DC OVERVOLTAGE RELAY
- 50 OVERCURRENT RELAY - INSTANTANEOUS
- 51 OVERCURRENT RELAY - TIME DELAY
- 64 GROUND PROTECTIVE RELAY
- 86U UNIT LOCKOUT RELAY
- 39 PILOT EXCITER FIELD REDUCING CONTACTOR
- 87G DIFFERENTIAL CURRENT RELAY; G - GENERATOR, L - PILOT WIRE, T - TRANSFORMER & BUS
- X AUXILIARY DEVICE
- 52N NEUTRAL A.C.B. AUXILIARY CONTACT
- 59 A C OVERVOLTAGE RELAY
- * THERE WILL BE TWO NEUTRAL BREAKERS FOR EACH GROUP OF GENERATORS, ONE WILL BE A RESERVE BREAKER

NOTE:
WIRING FOR GENERATOR NO.1 TYPICAL FOR ALL UNITS

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BOSTON, MASSACHUSETTS

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

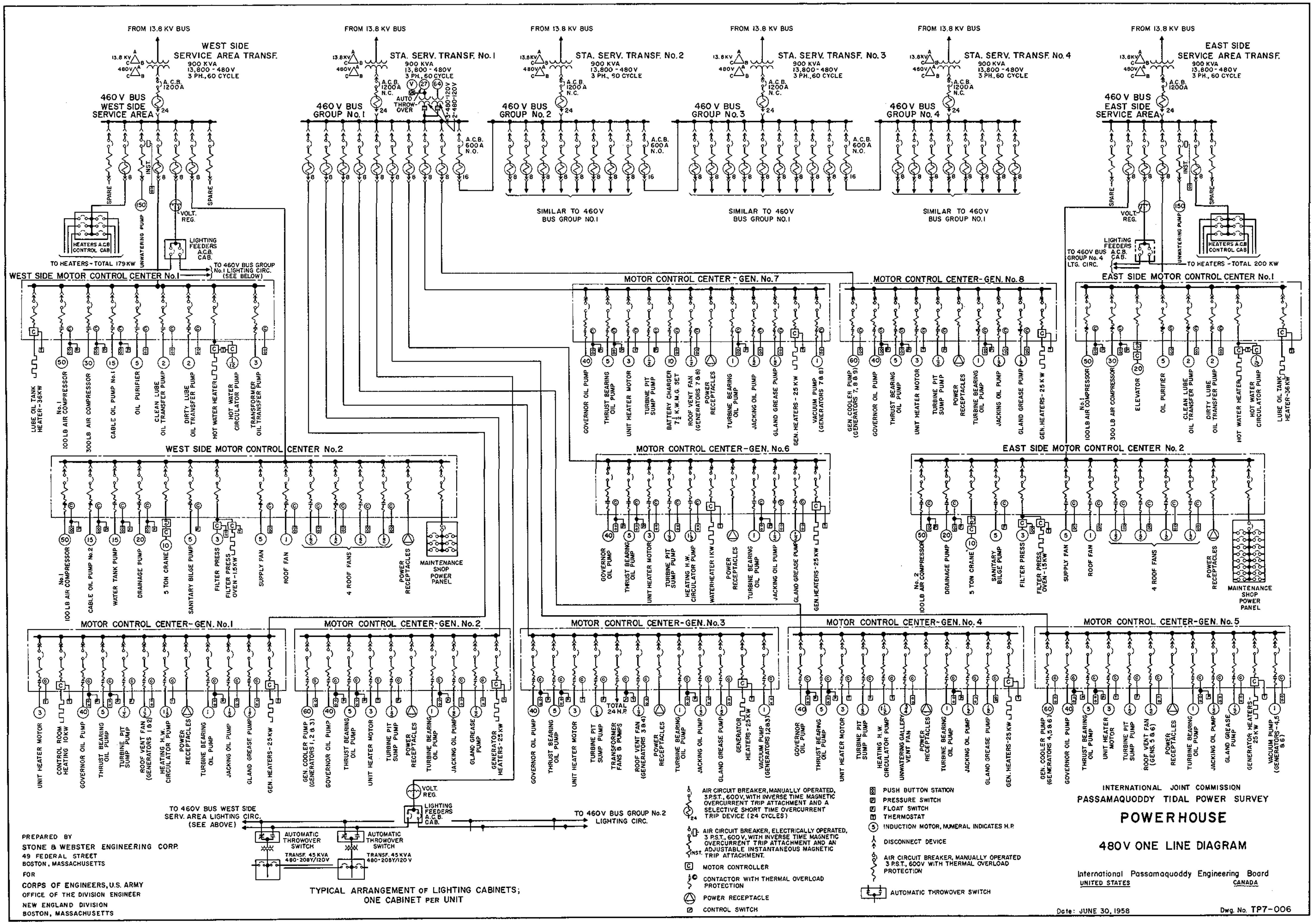
# POWERHOUSE

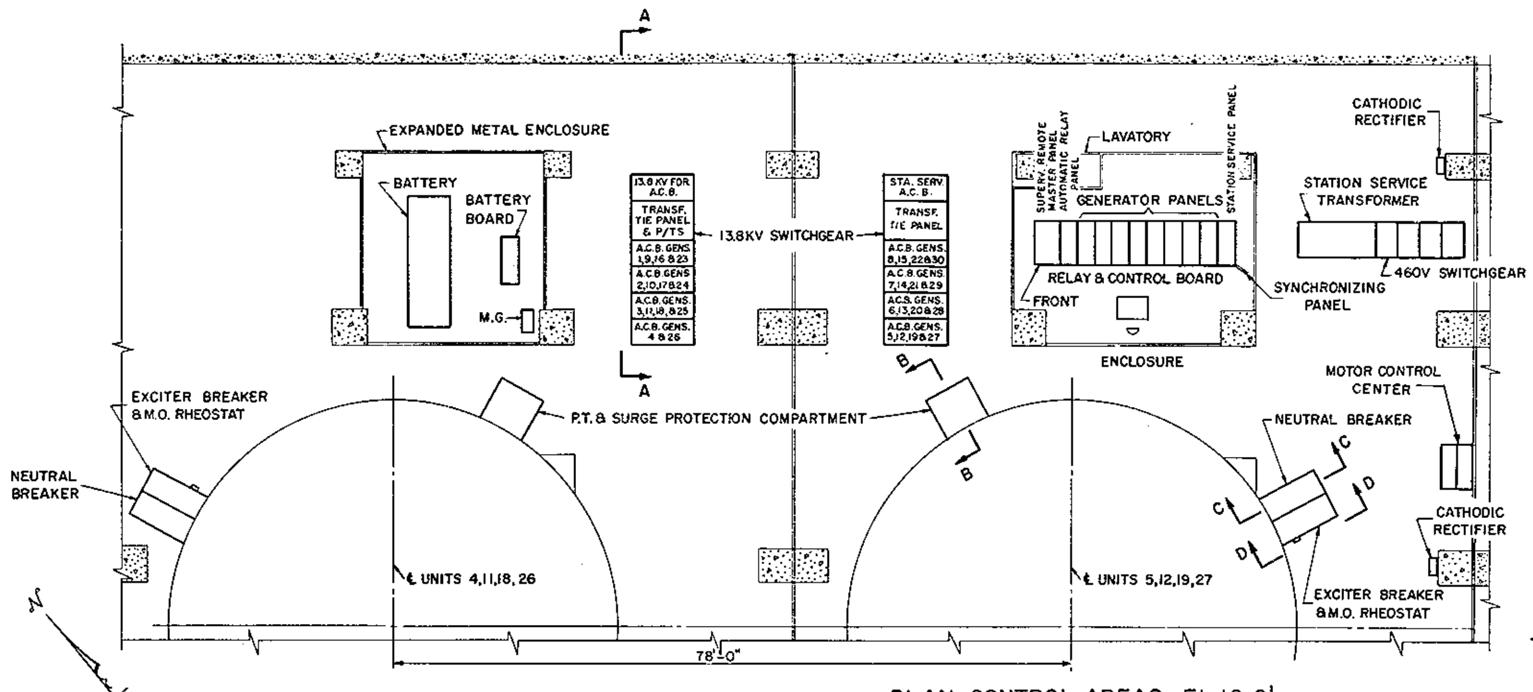
## MAIN ONE LINE DIAGRAM

International Passamaquoddy Engineering Board
UNITED STATES — CANADA

Date: JUNE 30, 1958

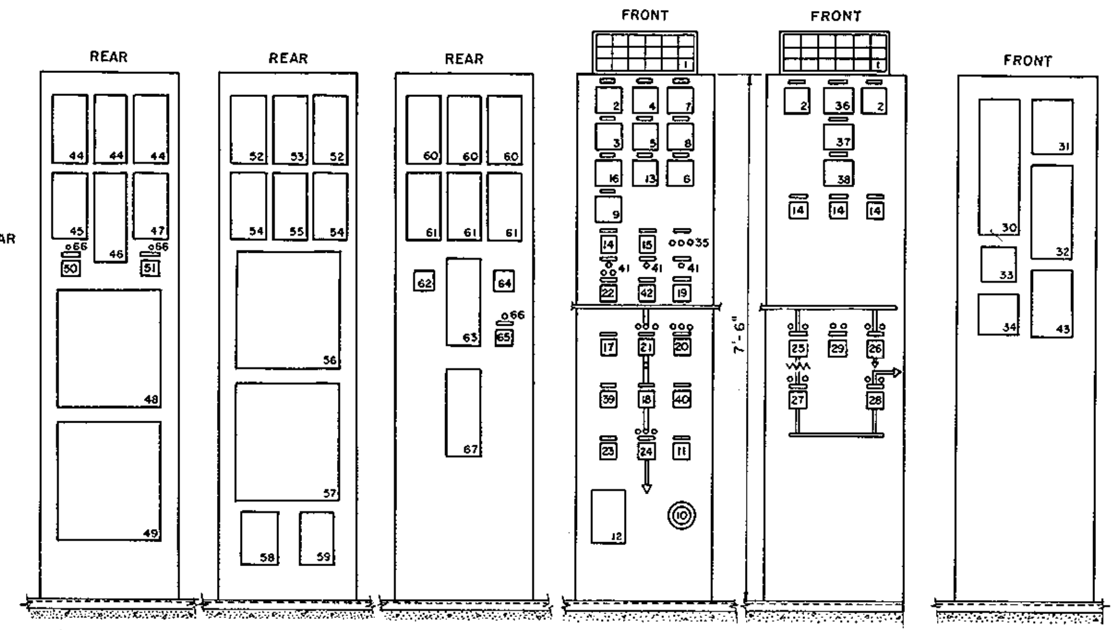
Dwg. No. TP7-005


FROM 13.8 KV BUS
WEST SIDE SERVICE AREA TRANSF. 900 KVA 13,800-480V 3 PH., 60 CYCLE
STA. SERV. TRANSF. No. 1 900 KVA 13,800-480V 3 PH., 60 CYCLE
STA. SERV. TRANSF. No. 2
STA. SERV. TRANSF. No. 3
STA. SERV. TRANSF. No. 4
EAST SIDE SERVICE AREA TRANSF. 900 KVA 13,800-480V 3 PH., 60 CYCLE
460V BUS WEST SIDE SERVICE AREA
460V BUS GROUP No. 1
460V BUS GROUP No. 2
460V BUS GROUP No. 3
460V BUS GROUP No. 4
460V BUS EAST SIDE SERVICE AREA
SIMILAR TO 460V BUS GROUP NO. 1
WEST SIDE MOTOR CONTROL CENTER No. 1
WEST SIDE MOTOR CONTROL CENTER No. 2
EAST SIDE MOTOR CONTROL CENTER No. 1
EAST SIDE MOTOR CONTROL CENTER No. 2
MOTOR CONTROL CENTER-GEN. No. 1
MOTOR CONTROL CENTER-GEN. No. 2
MOTOR CONTROL CENTER-GEN. No. 3
MOTOR CONTROL CENTER-GEN. No. 4
MOTOR CONTROL CENTER-GEN. No. 5
MOTOR CONTROL CENTER-GEN. No. 6
MOTOR CONTROL CENTER-GEN. No. 7
MOTOR CONTROL CENTER-GEN. No. 8
TO HEATERS-TOTAL 179 KW
TO HEATERS-TOTAL 200 KW
TO 460V BUS WEST SIDE SERV. AREA LIGHTING CIRC. (SEE ABOVE)
TO 460V BUS GROUP No. 2 LIGHTING CIRC.
AUTOMATIC THROWOVER SWITCH
TRANSF. 45 KVA 480-208Y/120V
TYPICAL ARRANGEMENT OF LIGHTING CABINETS; ONE CABINET PER UNIT
AIR CIRCUIT BREAKER, MANUALLY OPERATED, 3P.S.T., 600V, WITH INVERSE TIME MAGNETIC OVERCURRENT TRIP ATTACHMENT AND A SELECTIVE SHORT TIME OVERCURRENT TRIP DEVICE (24 CYCLES)
AIR CIRCUIT BREAKER, ELECTRICALLY OPERATED, 3 P.S.T., 600V, WITH INVERSE TIME MAGNETIC OVERCURRENT TRIP ATTACHMENT AND AN ADJUSTABLE INSTANTANEOUS MAGNETIC TRIP ATTACHMENT.
MOTOR CONTROLLER
CONTACTOR WITH THERMAL OVERLOAD PROTECTION
POWER RECEPTACLE
CONTROL SWITCH
PUSH BUTTON STATION
PRESSURE SWITCH
FLOAT SWITCH
THERMOSTAT
INDUCTION MOTOR, NUMERAL INDICATES H.P.
DISCONNECT DEVICE
AIR CIRCUIT BREAKER, MANUALLY OPERATED 3 P.S.T., 600V WITH THERMAL OVERLOAD PROTECTION
AUTOMATIC THROWOVER SWITCH
PREPARED BY
STONE & WEBSTER ENGINEERING CORP.
49 FEDERAL STREET
BOSTON, MASSACHUSETTS
FOR
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASSACHUSETTS
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
POWERHOUSE
480V ONE LINE DIAGRAM
International Passamaquoddy Engineering Board
UNITED STATES
CANADA
Date: JUNE 30, 1958
Dwg. No. TP7-006




PLAN-CONTROL AREAS- EL.12.0'

0 5 10 15 20 25 30
SCALE - FEET




GENERATOR RELAY PANEL (TYPICAL)

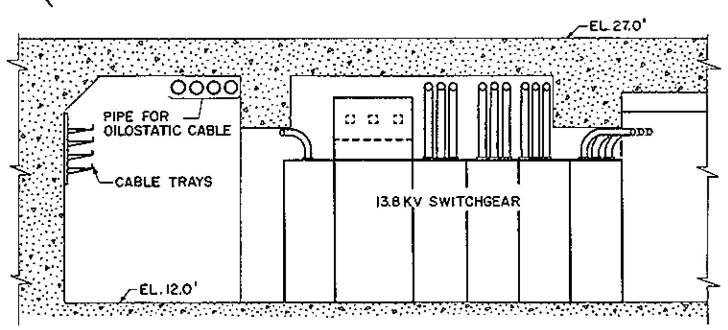
STATION SERVICE 13.8KV FDR & MAIN TRANSFER RELAY PANEL (TYPICAL)

AUTOMATIC RELAY PANEL (TYPICAL)

GENERATOR CONTROL PANEL (TYPICAL)

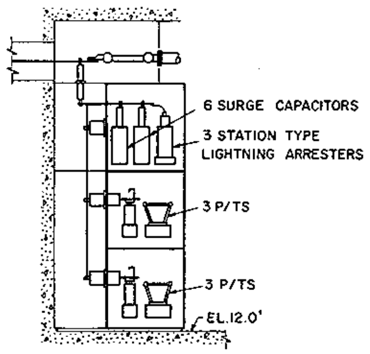
STATION SERVICE 13.8KV FDR. & MAIN TRANSFER CONTROL PANEL (TYPICAL)

AUTOMATIC RELAY PANEL (TYPICAL)

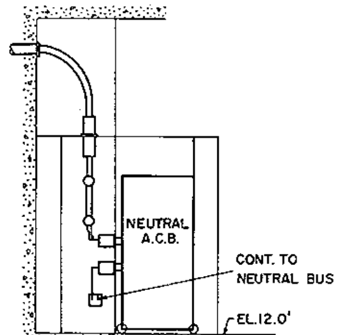



SECTION "A A"

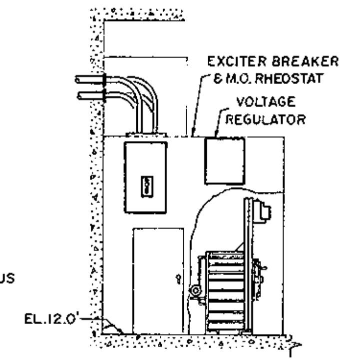
0 5 10 15
SCALE - FEET




"B B"




"C C"

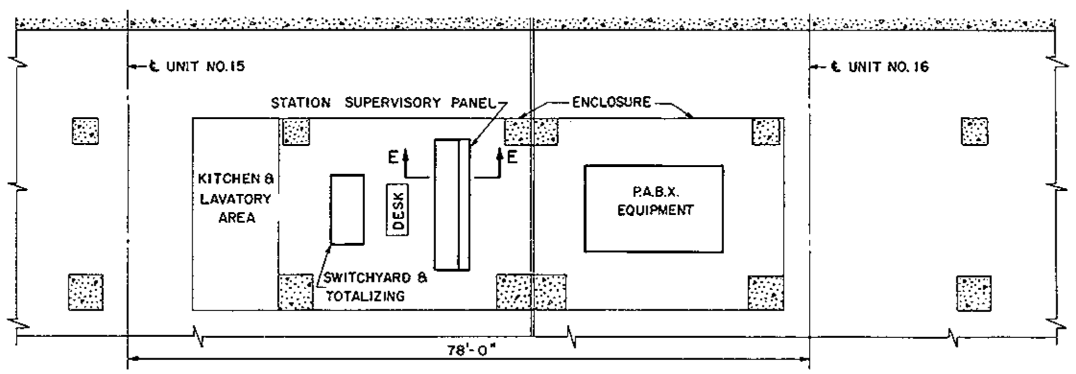



"D D"

0 2 4 6 8 10
SCALE - FEET
SECTIONS "B B" TO "E E"

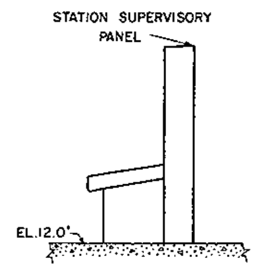
## EQUIPMENT SCHEDULE

| NO. | DESCRIPTION | NO. | DESCRIPTION |
|---|---|---|---|
| 1 | ANNUNCIATOR | 36 | A C AMMETER MAIN TRANSFORMER |
| 2 | A C AMMETER | 37 | INDICATING WATTMETER-MAIN TRANSFORMER |
| 3 | D C AMMETER | 38 | INDICATING VARMETER-MAIN TRANSFORMER |
| 4 | A C VOLTMETER | 39 | SPEED ADJUSTING CONTROL SWITCH |
| 5 | D C VOLTMETER | 40 | GATE LIMIT CONTROL SWITCH |
| 6 | POSITION IND.-TURBINE GATE OPENING & LIMIT | 41 | UNIT SUPERV. LMPS FOR UNIT RELAYS, GOV. CONT. & EXCIT'N |
| 7 | INDICATING WATTMETER | 42 | CROSS CURRENT COMPENSATING CUTOUT SWITCH |
| 8 | INDICATING VARMETER | 43 | GENERATOR GROUP NEUTRAL GROUND RELAY |
| 9 | TACHOMETER | 44 | GENERATOR DIFFERENTIAL RELAYS |
| 10 | VOLTAGE ADJUSTING RHEOSTAT | 45 | A C OVERVOLTAGE RELAY |
| 11 | VOLTAGE REGULATOR TRANSFER SWITCH | 46 | GENERATOR WATTHOUR TRANSMITTER |
| 12 | TRANSFER RELAY | 47 | EXCITER OVERVOLTAGE RELAY |
| 13 | SPEED ADJUSTING INDICATOR | 48 | GENERATOR FIELD TEMPERATURE RECORDER |
| 14 | AMMETER TRANSFER SWITCH | 49 | UNIT BEARING TEMPERATURE RECORDER |
| 15 | A C VOLTMETER TRANSFER SWITCH | 50 | GENERATOR DIFFERENTIAL AUXILIARY RELAY |
| 16 | D C AMMETER MAIN EXCITER FIELD | 51 | GEN. OVERVOLTAGE & NEUTRAL DIFF. AUX. RELAY |
| 17 | AUTO. SYNCH. CUTOUT SWITCH | 52 | STATION SERVICE OVERCURRENT RELAY |
| 18 | GENERATOR SYNCHRONIZING SWITCH | 53 | STATION SERVICE GROUND RELAY |
| 19 | EMERGENCY SHUTDOWN CONTROL SWITCH | 54 | 13.8 KV FEEDER OVERCURRENT RELAY |
| 20 | EXC. FLD. RHEOSTAT CONT. SW. WITH G.A. & R. LMPS | 55 | 13.8 KV FEEDER GROUND RELAY |
| 21 | GENERATOR A.C.B. CONT. SW. WITH G.A.&R. LMPS | 56 | GEN.-STATOR & MAIN TRANF. TEMP. RECORDER |
| 22 | MAIN EXC. FIELD A.C.B. CONT. SW. WITH R&G. LMPS | 57 | GEN. STATOR TEMPERATURE RECORDER |
| 23 | TRANSFER CONTROL SWITCH | 58 | STATION SERVICE WATTHOUR METER |
| 24 | GEN. NEUT. A.C.B. CONT. SW. WITH G.A.&R. LMPS | 59 | 13.8 KV FEEDER WATTHOUR METER |
| 25 | 13.8 KV STA. SERV. A.C.B CONT. SW. WITH G&R LMPS | 60 | BUS & TRANSFORMER DIFFERENTIAL RELAYS |
| 26 | 13.8 KV FDR. A.C.B. CONT. SW. WITH G.&R. LMPS | 61 | PILOT WIRE BACK-UP RELAYS |
| 27 | 480 V STA. SERV. A.C.B. CONT. SW. WITH G&R LMPS | 62 | PILOT WIRE MILLIVOLT METER |
| 28 | 480V ST. SER. BUS TIE A.C.B. CONT. SW. WITH G&R LMPS | 63 | PILOT WIRE DIFFERENTIAL RELAY |
| 29 | MN. TRANFORMER COOLERS CONT. SW. WITH G&R LMPS | 64 | PILOT WIRE TEST SWITCH |
| 30 | SYNCHRONIZING RELAY | 65 | BUS & TRANSFORMER DIFFERENTIAL AUX. RELAY |
| 31 | CHECK RELAY | 66 | INDICATING LAMP-WHITE COLOR CAP |
| 32 | SPEED MATCHING RELAY | 67 | MAIN TRANSF. WATTHOUR METER TRANSMITTER |
| 33 | TIMER | | |
| 34 | AUXILIARY RELAY FOR TIMER | | |
| 35 | ANNUN. BUTTONS SILENCE, RESET & TEST | | |




PLAN-SUPERVISORY CONTROL AREA EL.12.0'

0 5 10 15 20 25 30
SCALE - FEET




"E E"

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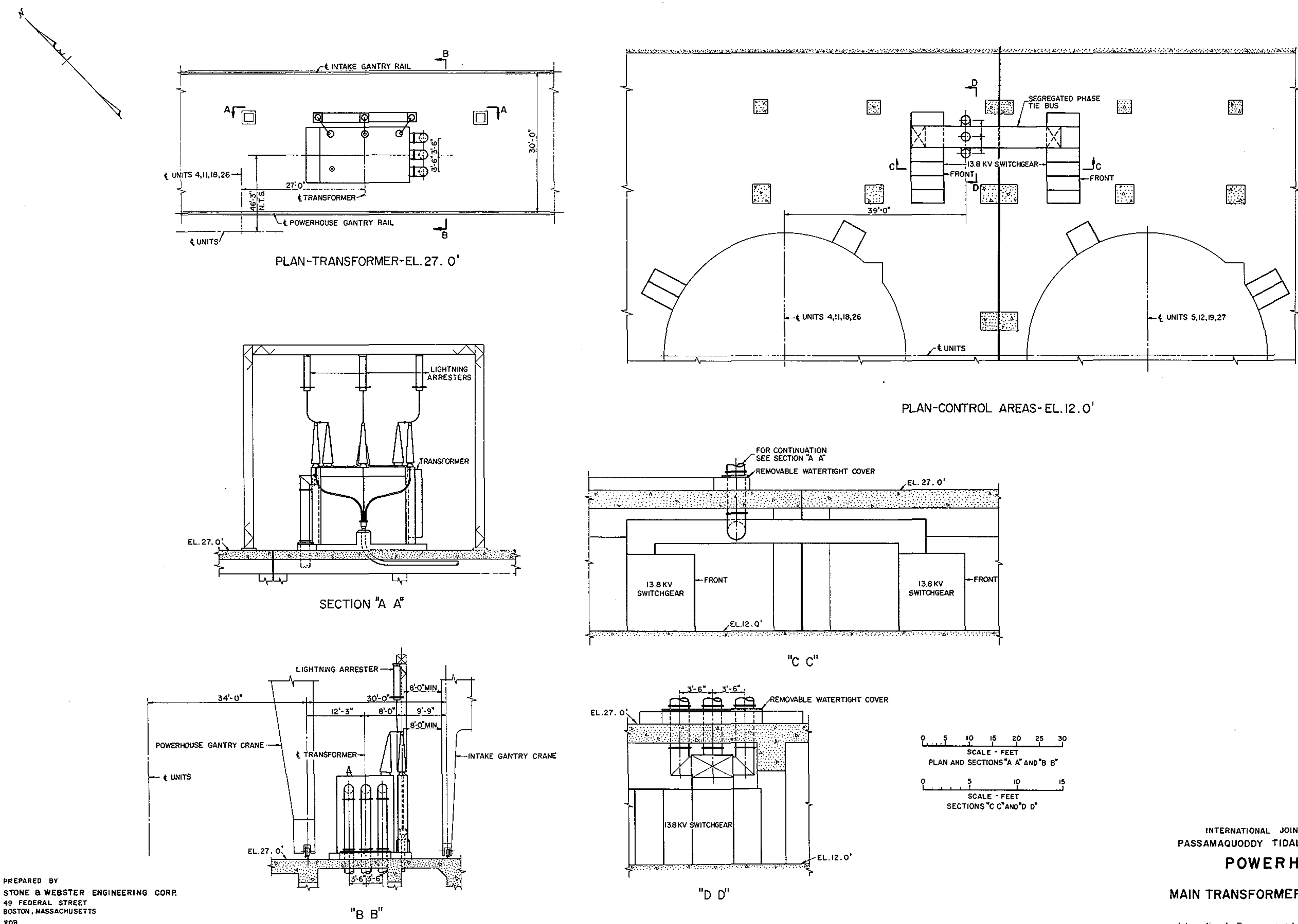
PASSAMAQUODDY TIDAL POWER SURVEY

# POWERHOUSE

## CONTROL EQUIPMENT ARRANGEMENT

International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958 Dwg. No. TP7-007

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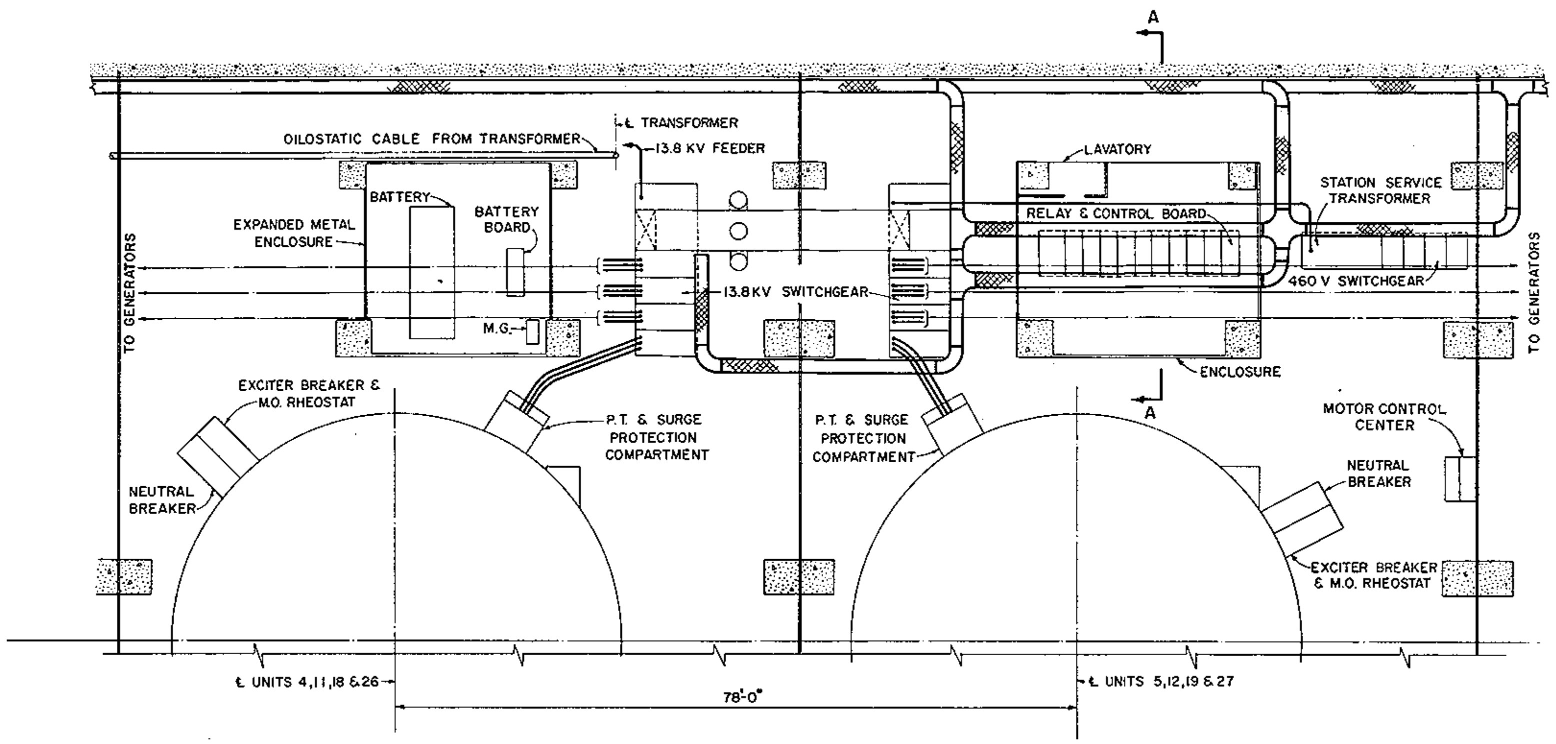
PASSAMAQUODDY TIDAL POWER SURVEY

## POWERHOUSE

### MAIN TRANSFORMER ARRANGEMENT

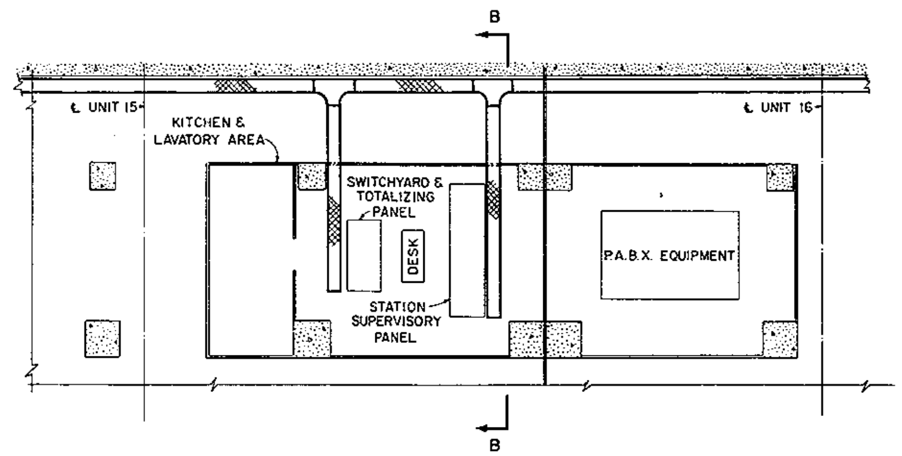
International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958 Dwg. No. TP7-008



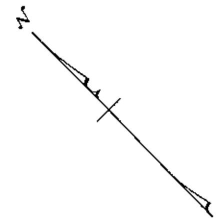

PLAN-CONTROL AREAS-EL. 12.0'

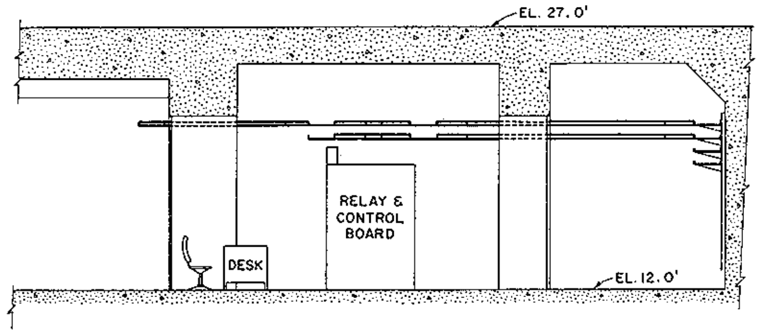
0 5 10 15 20 25
SCALE-FEET



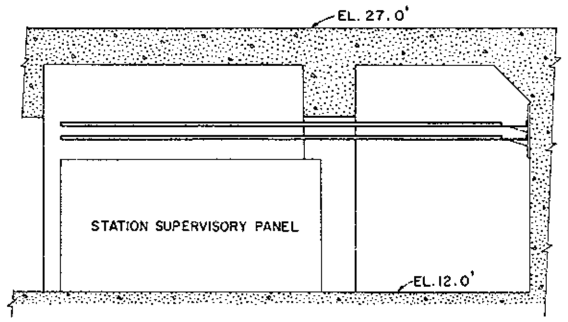

PLAN-SUPERVISORY CONTROL AREA-EL. 12.0'

0 5 10 15 20 25
SCALE-FEET




"A A"




"B B"

0 5 10 15 20
SCALE-FEET

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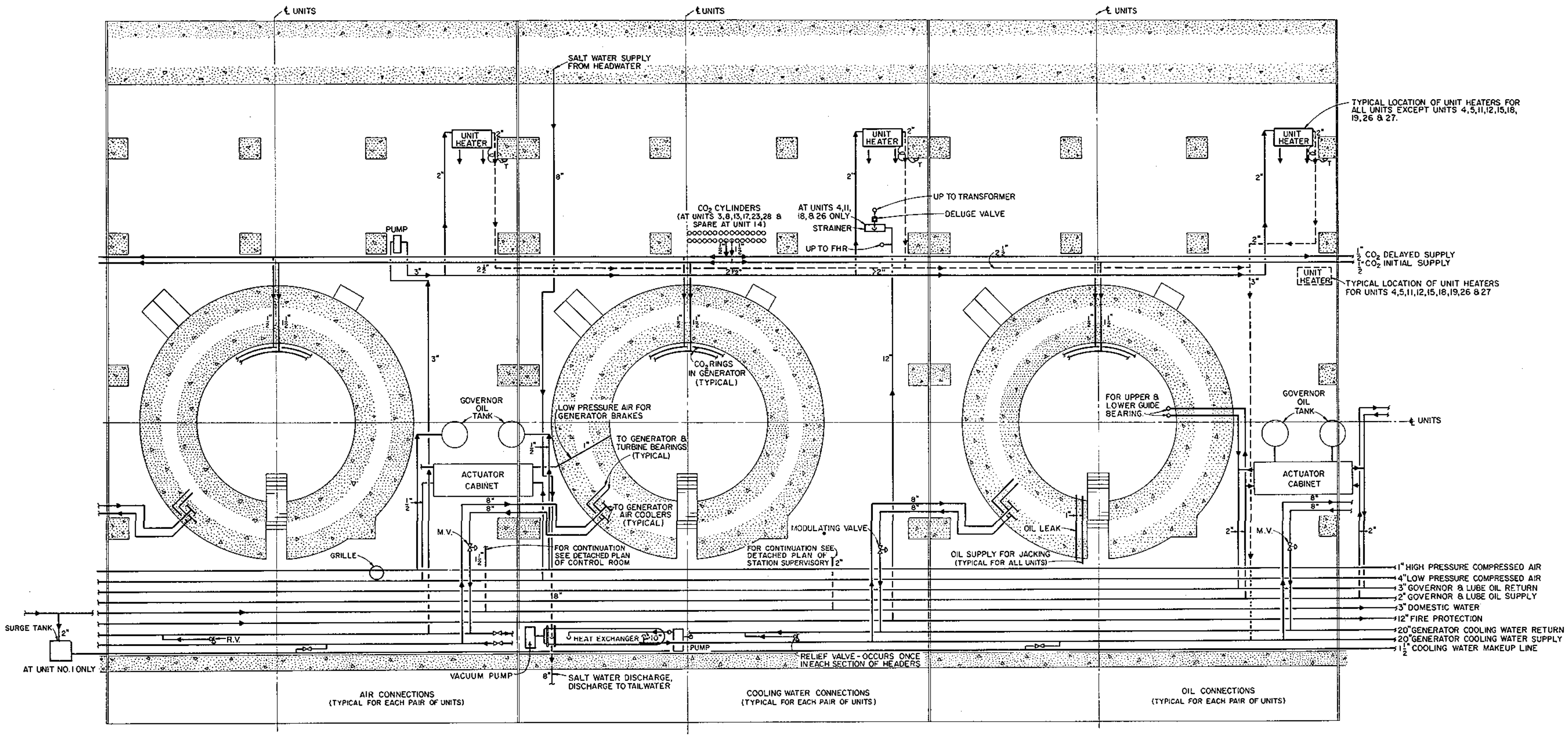
PASSAMAQUODDY TIDAL POWER SURVEY

**POWERHOUSE**

**CABLE TRAY ARRANGEMENT**

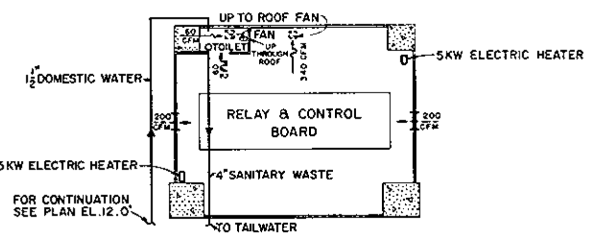
International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958 Dwg. No. TP7-009

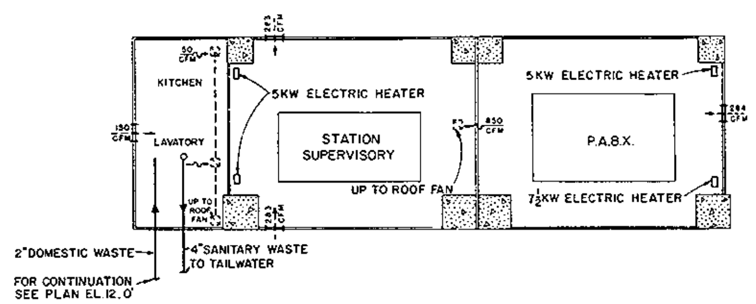



PLAN-ELEVATION 12.0'

0 5 10 15 20 25 30
SCALE-FEET




DETACHED PLAN-CONTROL ROOM
AT UNITS 5, 12, 19, & 27 ONLY




DETACHED PLAN - STATION SUPERVISORY
AT UNIT 15 ONLY

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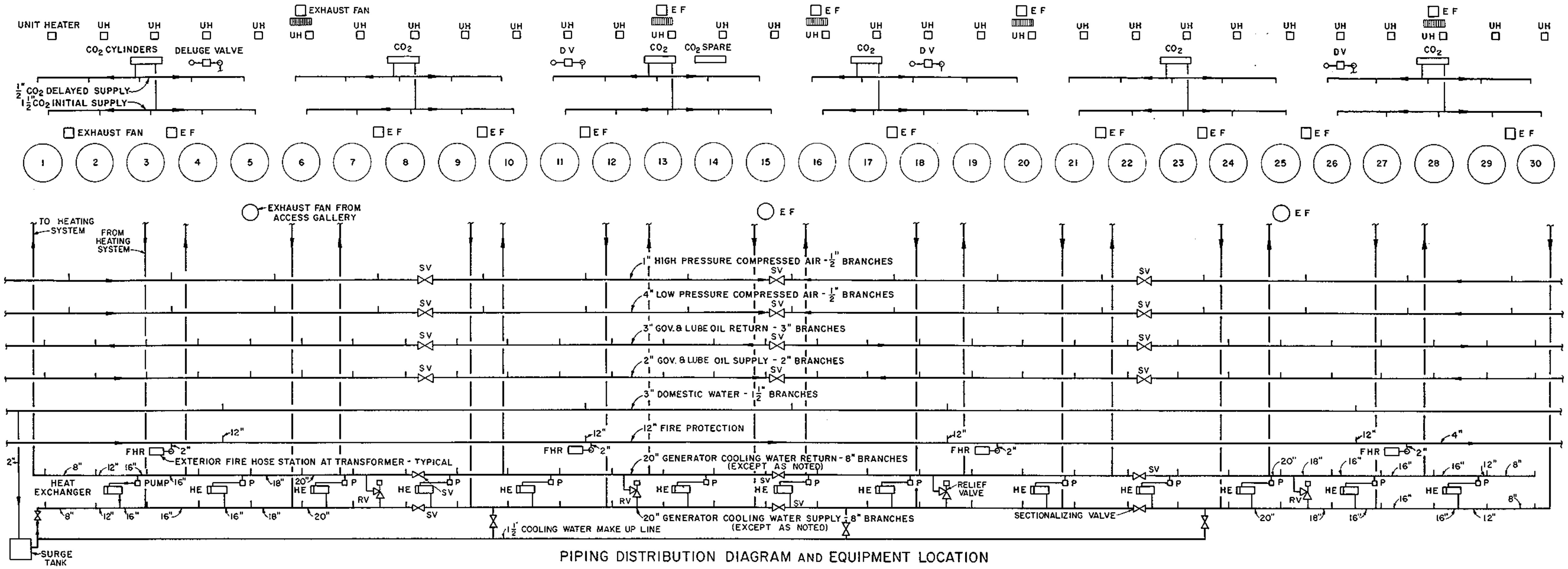
## POWERHOUSE

## PIPING CONNECTIONS AT GENERATORS

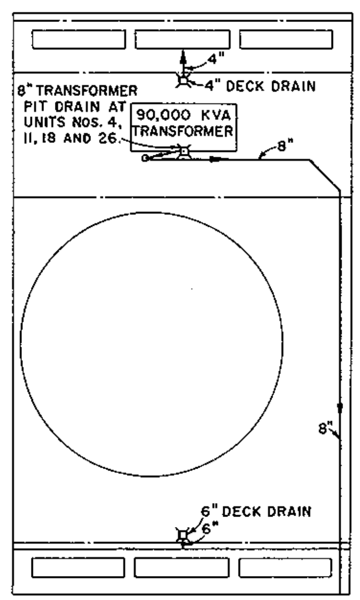
International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958
Dwg. No. TP7-010

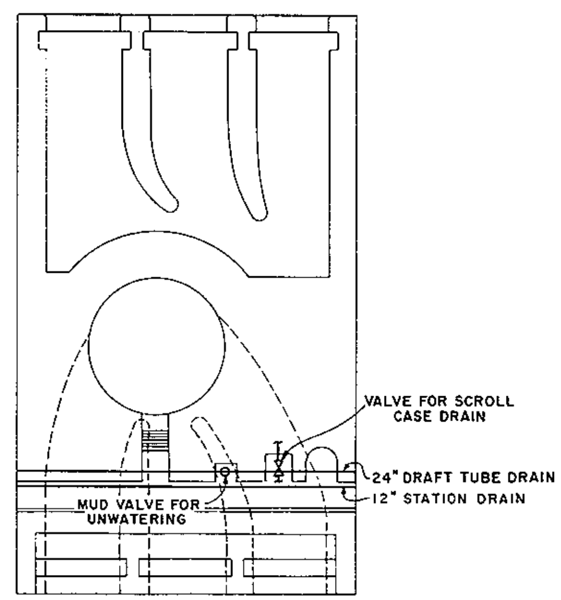



PIPING DISTRIBUTION DIAGRAM AND EQUIPMENT LOCATION

NOT TO SCALE




PLAN - ROOF DECK - EL. 27.0'




PLAN - ACCESS GALLERY - EL. -43.5'

0 10 20 30 40 50
SCALE - FEET

LEGEND
- $CO_2$ - CARBON DIOXIDE
- DV - DELUGE VALVE
- EF - EXHAUST FAN
- FHR - FIRE HOSE REEL
- HE - HEAT EXCHANGER
- P - PUMP
- RV - RELIEF VALVE
- SV - SECTIONALIZING VALVE
- UH - UNIT HEATER

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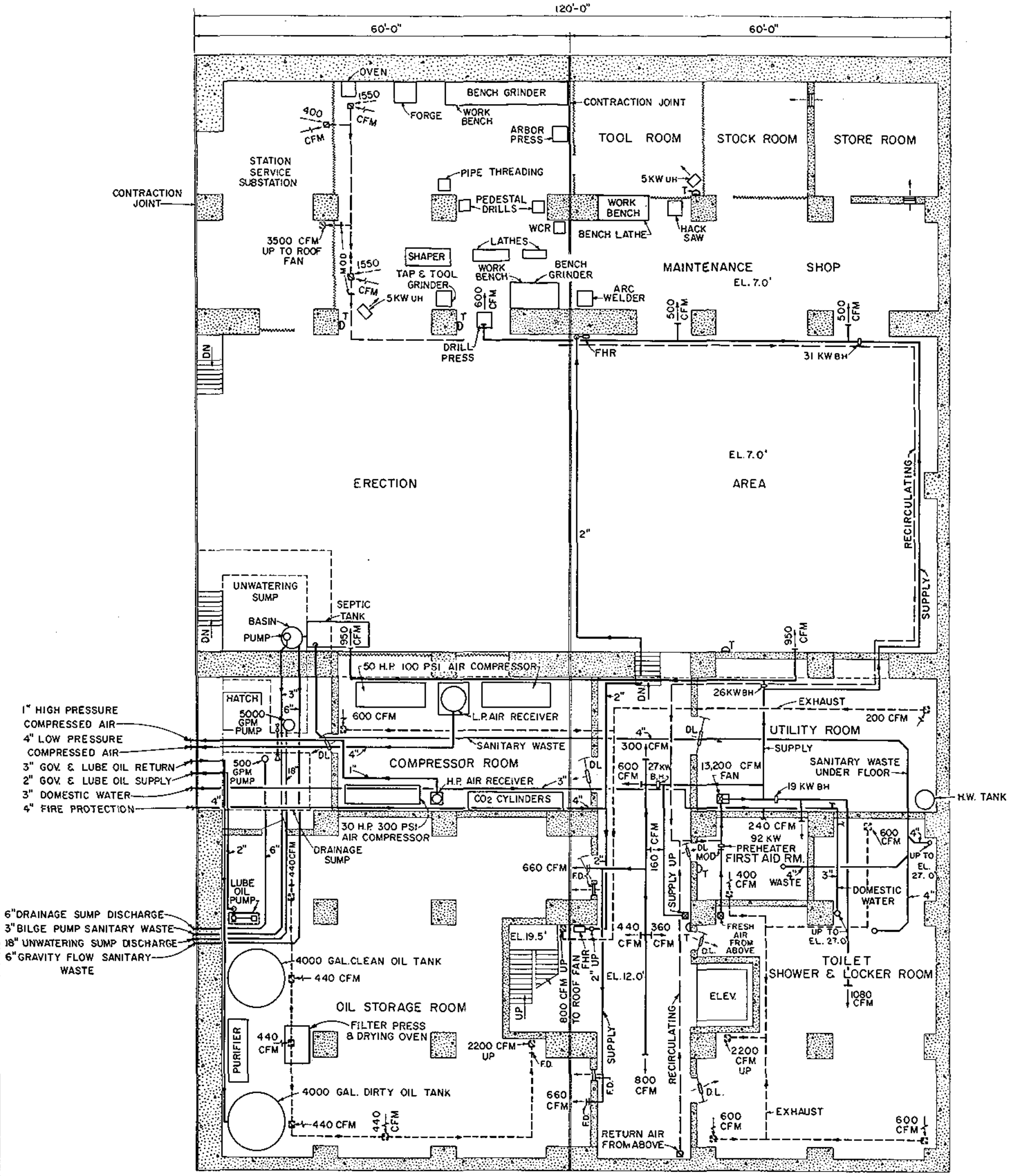
PASSAMAQUODDY TIDAL POWER SURVEY

## POWERHOUSE

## PIPING AND EQUIPMENT ARRANGEMENT

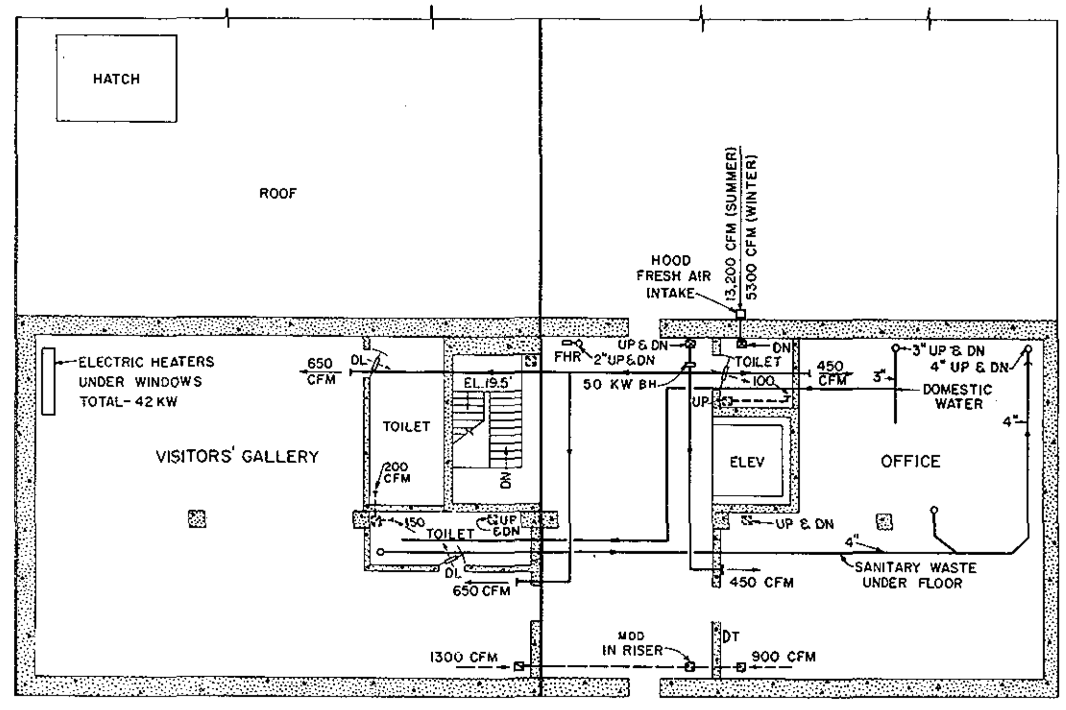
International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958 Dwg. No. TP7-011

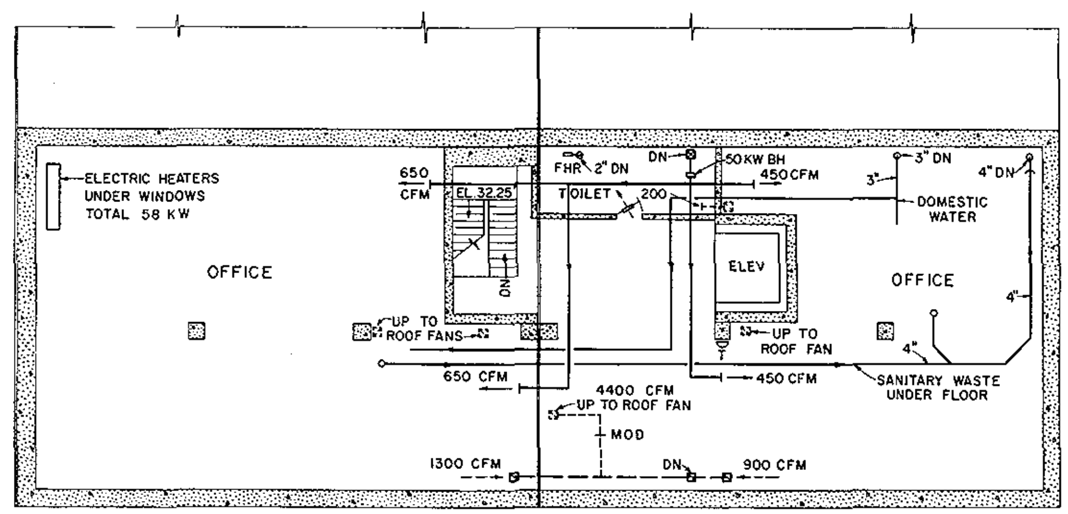



PLAN-ELEV. 7.0' & 12.0'

0 5 10 15 20 25 30
SCALE-FEET




PART PLAN-ELEV. 27.0'




PLAN-ELEV. 37.5'

NOTE:
FOR DETAILED ARRANGEMENT OF TOILETS, SHOWER AND LOCKER ROOMS SEE PLATE IV.

LEGEND
BH - BOOSTER HEATER
DL - DOOR LOUVER
FD - FIRE DAMPER
FHR - FIRE HOSE RACK
HW - HOT WATER
MOD - MOTOR OPERATED DAMPER
T - THERMOSTAT
UH - UNIT HEATER
WCR - WATER COOLER

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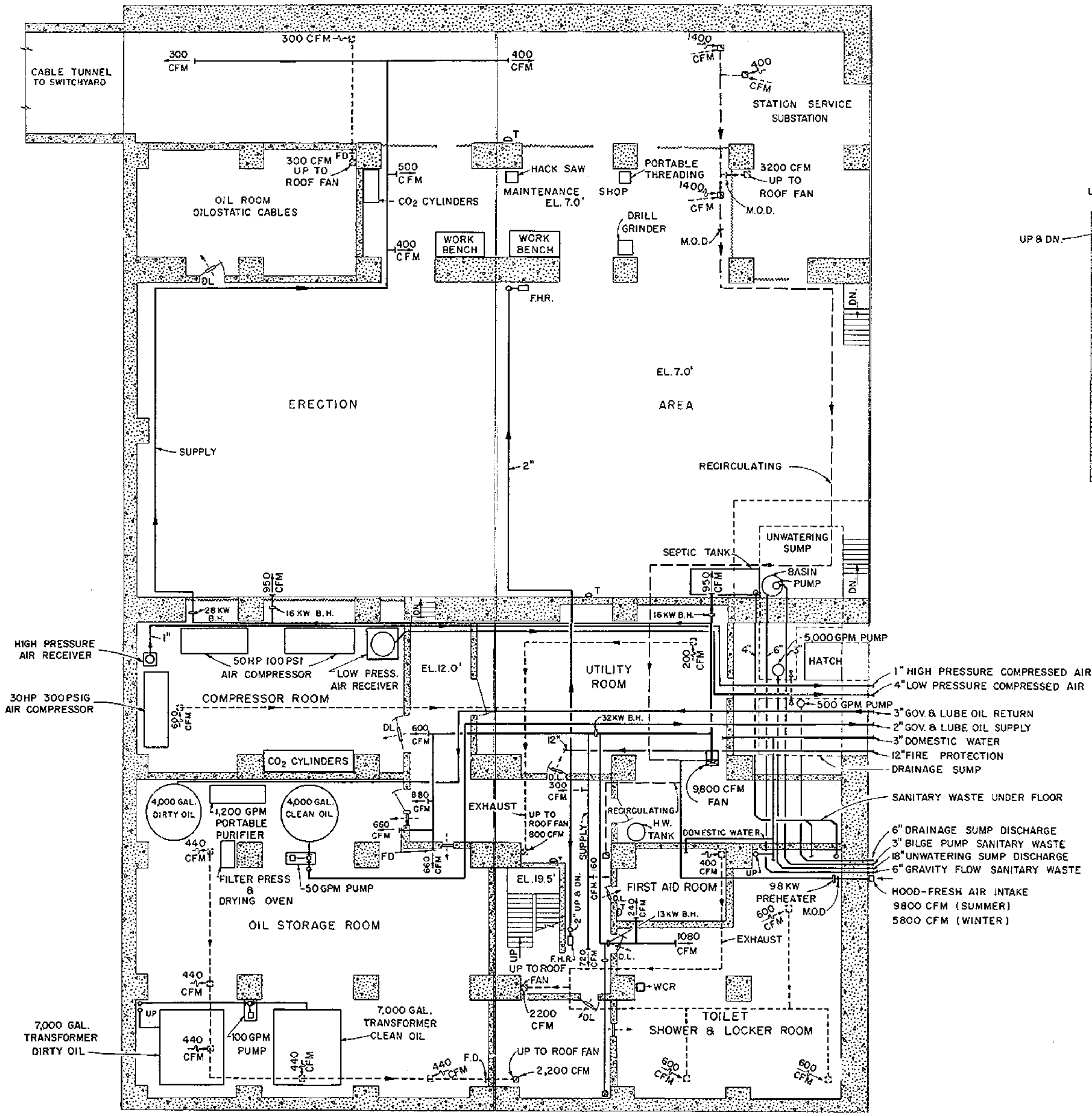
PASSAMAQUODDY TIDAL POWER SURVEY

**POWERHOUSE**

**EQUIPMENT ARRANGEMENT**
**EAST SERVICE BAY**

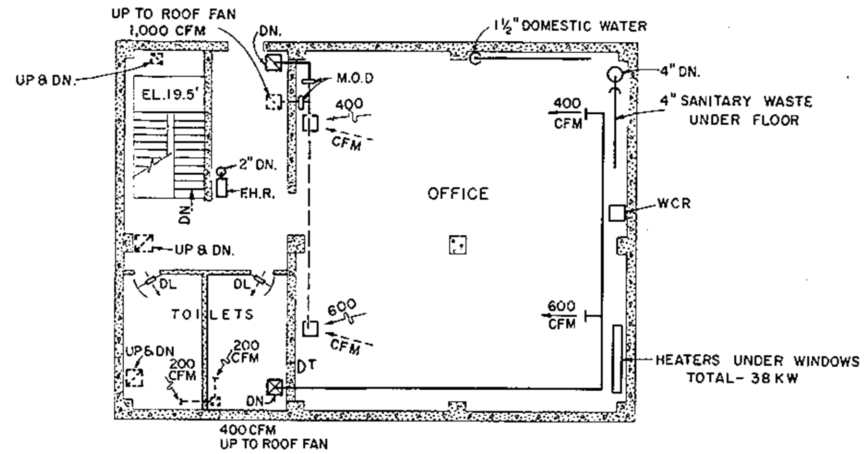
International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958
Dwg. No. TP7-012




PLAN-ELEV. 7.0' & 12.0'

0 5 10 15 20 25 30
SCALE - FEET




PLAN-ELEV. 27.0'

NOTE:
FOR DETAILED ARRANGEMENT OF TOILETS, SHOWER AND LOCKER ROOMS SEE PLATE IX

LEGEND
- BH - BOOSTER HEATER
- DL - DOOR LOUVER
- FD - FIRE DAMPER
- FHR - FIRE HOSE RACK
- HW - HOT WATER
- MOD - MOTOR OPERATED DAMPER
- T - THERMOSTAT
- UH - UNIT HEATER
- WCR - WATER COOLER

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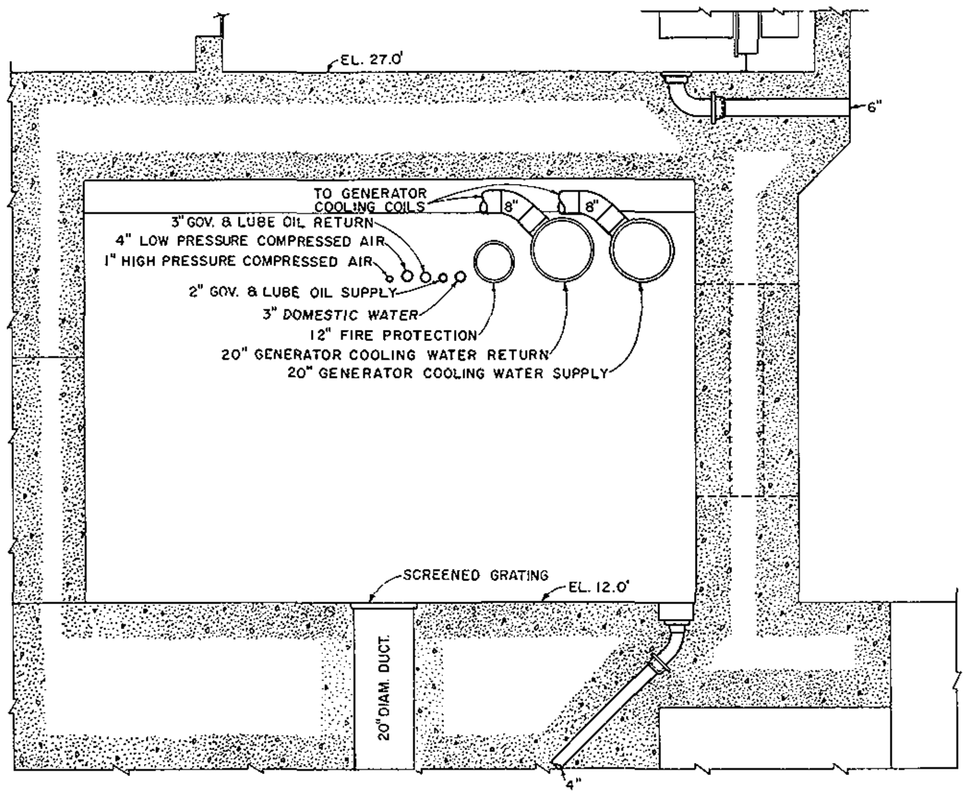
PASSAMAQUODDY TIDAL POWER SURVEY

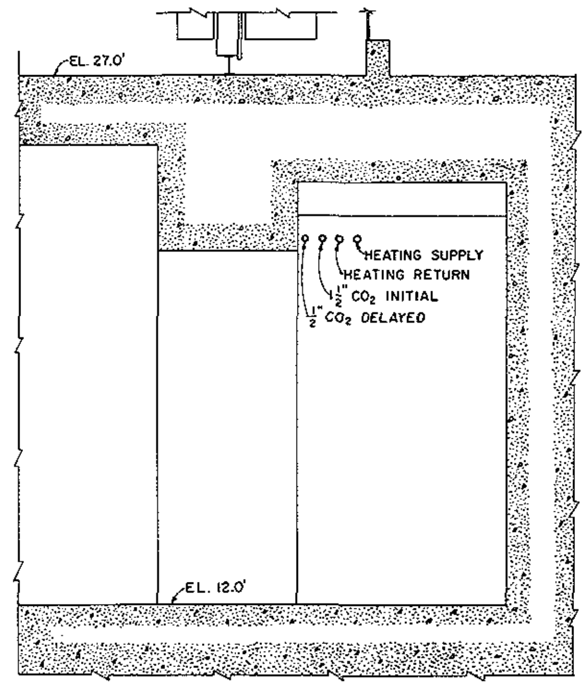
# POWERHOUSE
## EQUIPMENT ARRANGEMENT
## WEST SERVICE BAY

International Passamaquoddy Engineering Board
UNITED STATES CANADA

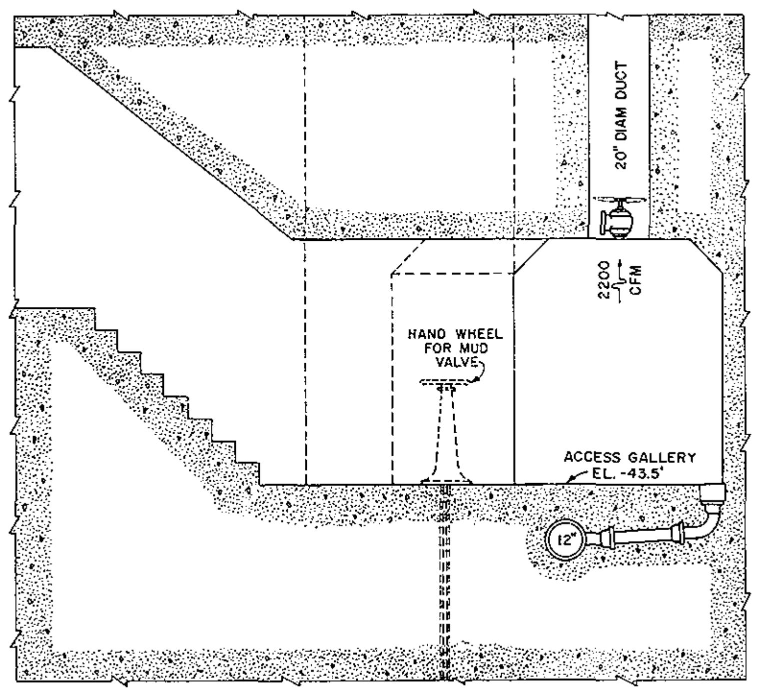
Date: JUNE 30, 1958 Dwg. No. TP7-013



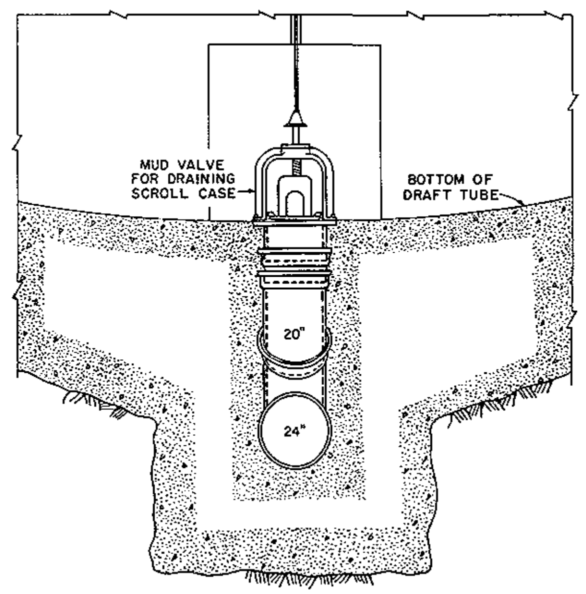

SECTION THRU TAILWATER TURBINE GALLERY



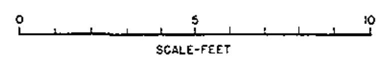

SECTION THRU HEADWATER TURBINE GALLERY




SECTION THRU ACCESS GALLERY




SECTION THRU UNWATERING PIPE

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PASSAMAQUODDY TIDAL POWER SURVEY

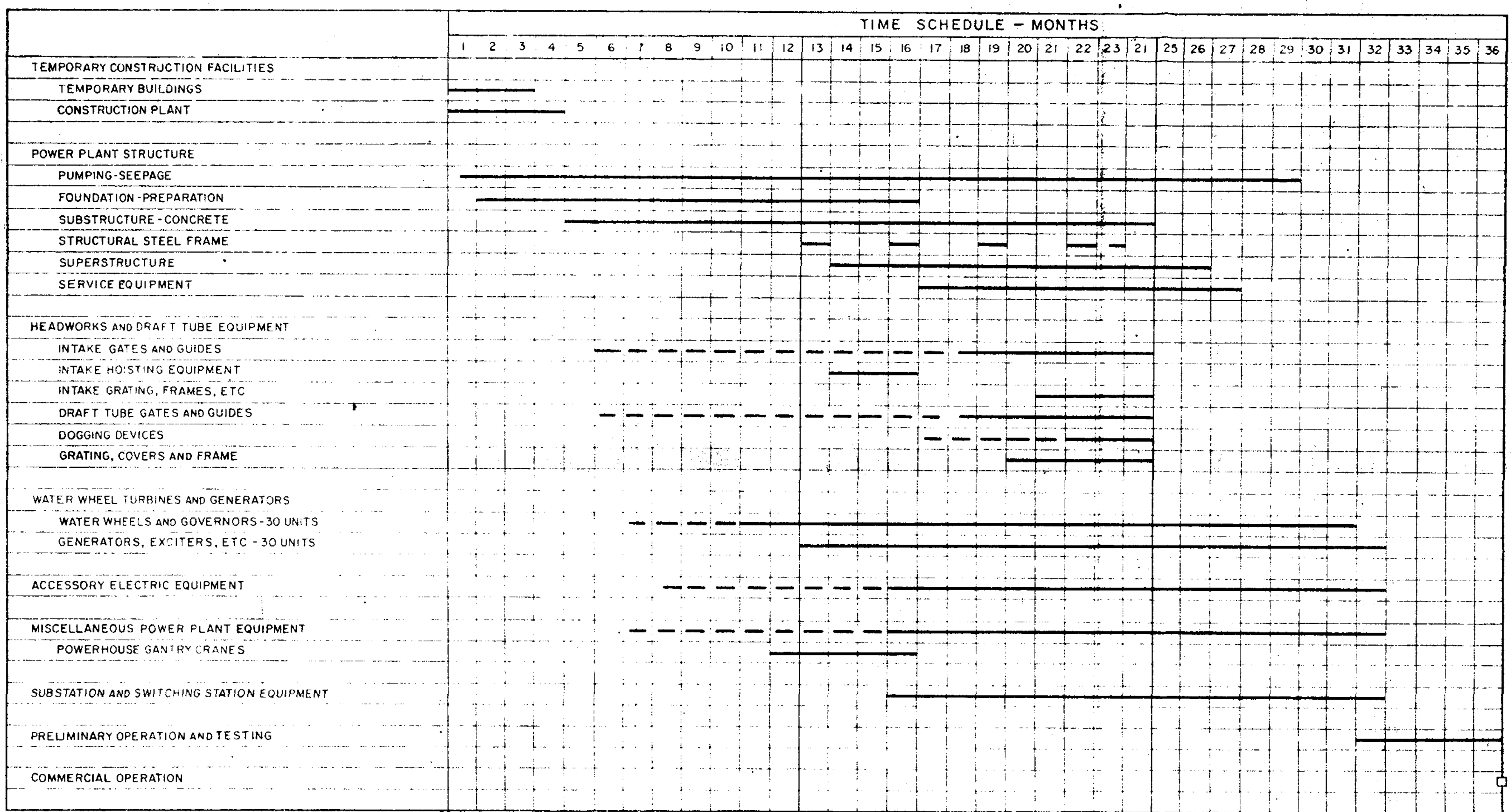
## POWERHOUSE

## MISCELLANEOUS PIPING SECTIONS

International Passamaquoddy Engineering Board
UNITED STATES CANADA

Date: JUNE 30, 1958 Dwg. No. TP7-014

PLATE XV




BASED ON EXCAVATION AND COFFERDAM WORK COMPLETED
BEFORE STARTING WORK ON POWER PLANT

—— —— INTERMITTENT CONSTRUCTION
———— CONTINUOUS CONSTRUCTION

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

POWERHOUSE

CONSTRUCTION PROGRESS CHART

International Passamaquoddy Engineering Board
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BOSTON, MASSACHUSETTS

TP7-015

# APPENDIX

March 12, 1958

J.O.No. 9945

Division Engineer,
Corps of Engineers, U.S. Army,
Office of the Division Engineer,
New England Division,
150 Causeway Street,
Boston 15, Massachusetts.

Attention Mr. R. D. Field

Dear Sirs:

TYPE OF POWERHOUSE
PASSAMAQUODDY TIDAL POWER PROJECT

Pursuant to Contract No. DA-19-016-CIV ENG-58-9 dated August 5, 1957, we have studied alternative arrangements of major equipment and various types of powerhouses to determine the most suitable type of structure for the Passamaquoddy Tidal Power Plant. This letter outlines our studies and presents our recommendation.

Three alternative types of powerhouses have been studied: indoor, semi-outdoor and outdoor. Drawings showing general arrangements have been prepared as follows:

9945-HD-012258 - Outdoor Powerhouse - Typical Cross Section
9945-HD-012058 - Outdoor Powerhouse - Plan - Elev. 27.0 & Elev. 12.0
9945-HD-012958 - Indoor Powerhouse - Typical Cross Section
9945-HD-012758 - Indoor Powerhouse - Plan - Elev. 27.0 & Elev. 12.0
9945-HD-013158 - Semi-Outdoor Powerhouse - Plans & Section
9945-HD-021358 - Semi-Outdoor & Outdoor Service Bay - Plan Elev. 27.0 & Elev. 12.0
9945-HD-021458 - Indoor Service Bay - Plan Elev. 27.0 & Elev. 12.0

Two prints of each drawing were turned over to you during our meeting held February 27, 1958, when we discussed and compared the various layouts. For convenience, a photostatic reduction of each drawing is attached.

The conference notes of that meeting review the design approach followed in developing each layout. To avoid unnecessary duplication, reference is made to those notes for a more detailed description.

Briefly, all powerhouse designs were based on similar equipment layouts for 30 - 10,000 kw units as follows:

> Units tied together electrically in groups of five, so that there would be one operating center and one 57,000 kva transformer for each five units; transformers located on the intake deck, an ideal location in terms of powerhouse cost, proximity to generators and electrical control equipment, and direction for take-off of overhead transmission lines to switchyard; erection and service bays provided at both ends of the powerhouse; control room located near the center of the powerhouse; equipment rooms and offices located adjacent to the service bays with the major portion of office space being located at the south (Eastport) end of the powerhouse.

In all three types of powerhouses, layouts below El. 27.0 are essentially the same. Above El. 27.0, the outdoor-type layout shows circular weather-proofed generator housings with removable hatches; the semi-outdoor layout shows a continuous light framed housing with rectangular removable hatches over the generators and powerhouse gantry cranes straddling the housing; and the indoor layout shows a typical superstructure housing the overhead bridge cranes, as well as the units. The designs contemplate that all gantry cranes will be self-propelled and that powerhouse gantry cranes will be housed-in to provide protection against inclement weather.

Estimated cost differentials show that the outdoor-type of powerhouse would be the most economical to construct. For comparative purposes, in estimating the cost of superstructure for the semi-outdoor and indoor stations, we have assumed a minimum type of siding and roofing (Robertson's 24 gage V-Beam Galbestos siding and 14 gage long-span Q-Decking). On this basis, we estimate that incremental costs for the other two types of stations would be:

| | |
|---|---|
| Semi-outdoor | $800,000 |
| Indoor | $2,500,000 |

In the event a more durable type of siding and roofing is required, these differentials would be substantially increased.

The semi-outdoor type of powerhouse possesses no significant advantage over the outdoor type. Protection of equipment against inclement weather during and following construction would be about the same. Access area at the El. 27.0 level would be more restricted in the semi-outdoor layout, and finally, it would cost more than the outdoor plant. Consequently, the choice between these two types is obviously in favor of the outdoor powerhouse.

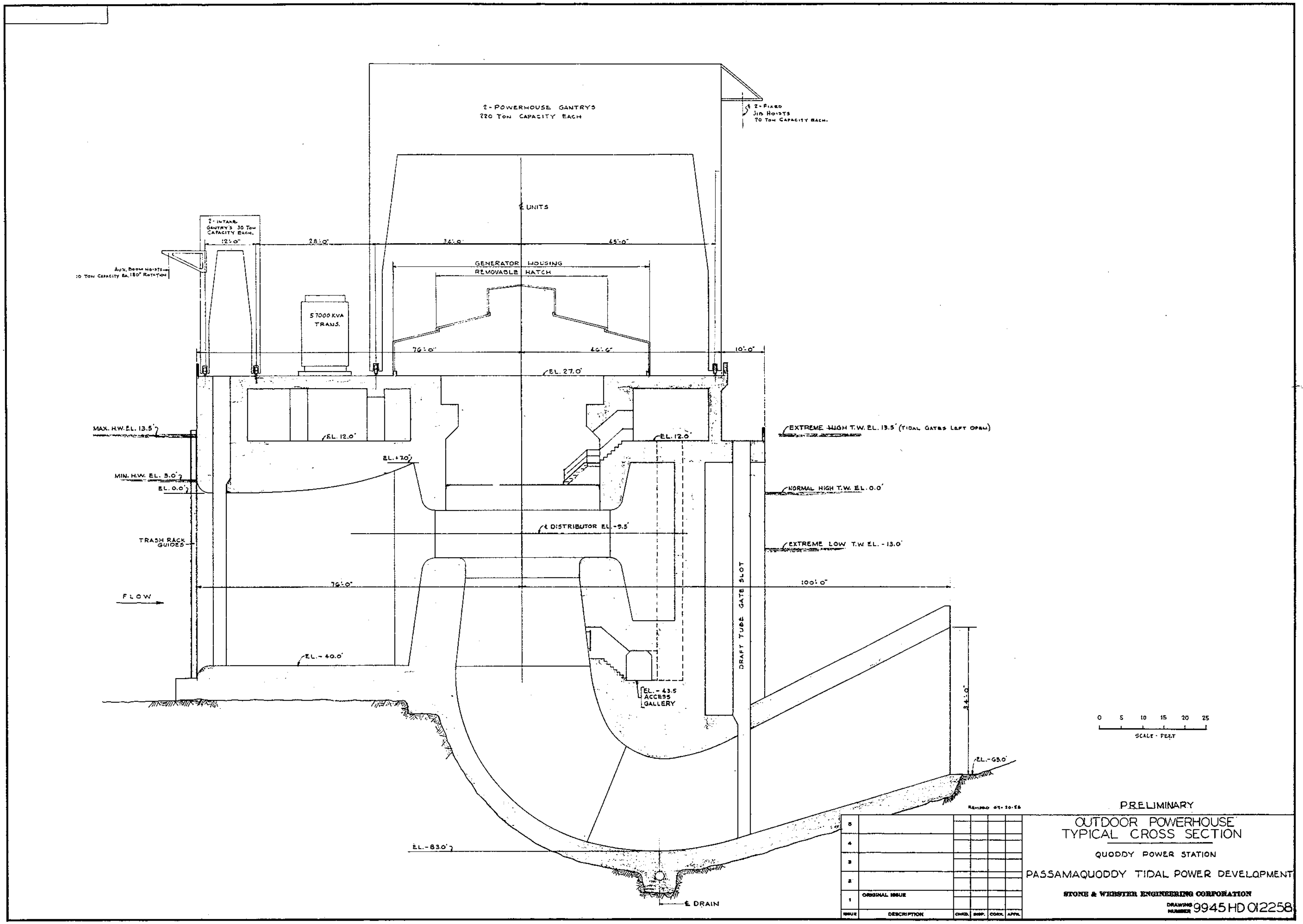
In view of the large difference in cost between the indoor and outdoor types of powerhouses and the fact that the housed-in powerhouse gantry cranes will afford protection to the units against inclement weather, we recommend that the outdoor type of powerhouse be adopted for the Passamaquoddy Tidal Power Plant. In our meeting of February 27, you concurred with this recommendation.

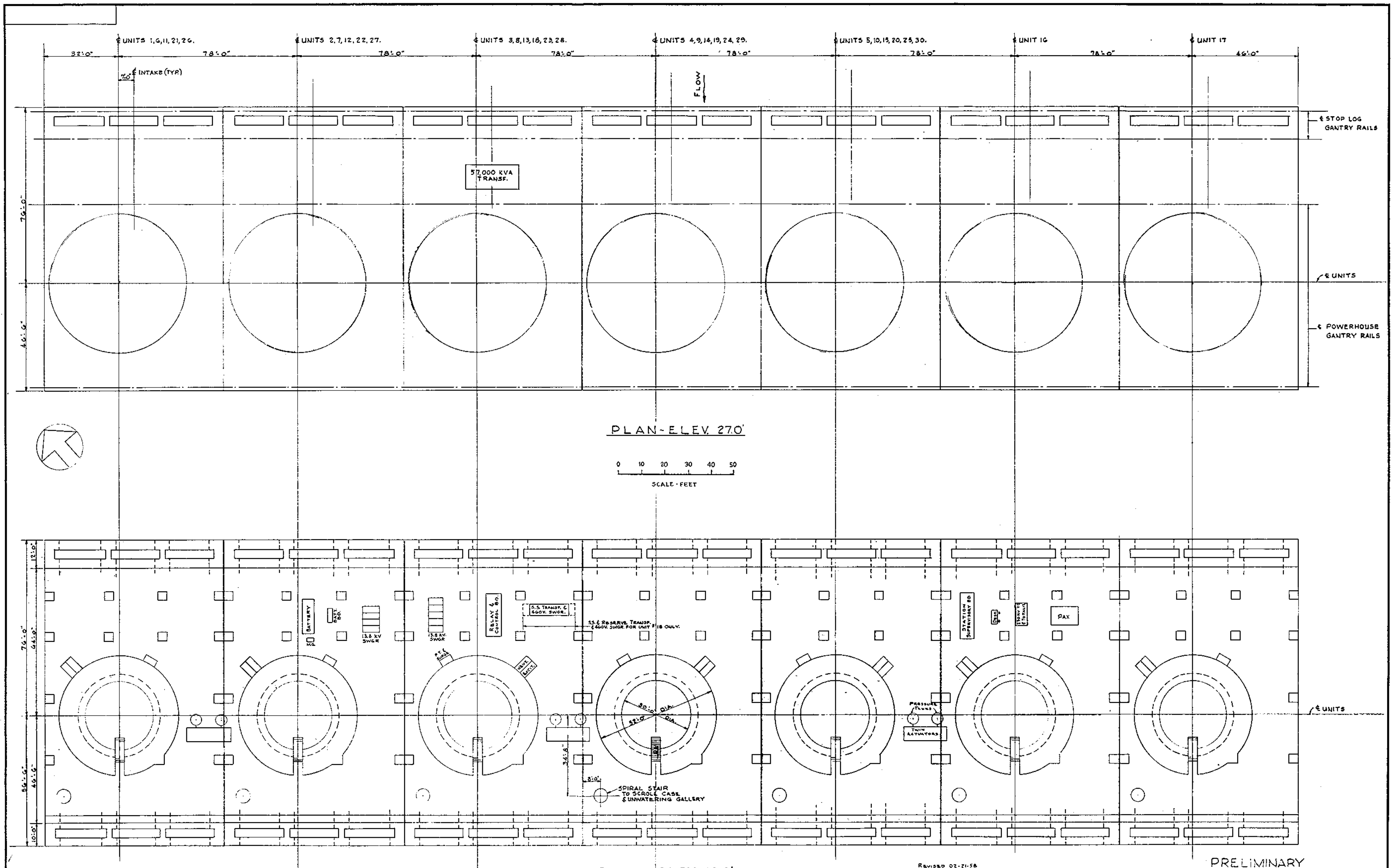
We shall now prepare design memoranda covering the various systems and equipment required for the outdoor-type powerhouse. These memoranda will, of course, be for the electrical grouping you requested of two 7-unit groups and two 8-unit groups with four Oilostatic transmission cables, rather than the six 5-unit groups with six overhead transmission lines that had served as a basis for our studies up to this time.

Yours very truly,

F. W. Argue,
Engineering Manager.

Enclosures


2-POWERHOUSE GANTRYS
220 TON CAPACITY EACH
℄ 2-FIXED JIB HOISTS
70 TON CAPACITY EACH.
℄ UNITS
2-INTAKE GANTRY'S 30 TON CAPACITY EACH.
12'-0"
28'-0"
34'-0"
45'-0"
AUX. BOOM HOISTS
10 TON CAPACITY EA. 180° ROTATION
GENERATOR HOUSING
REMOVABLE HATCH
57000 KVA
TRANS.
76'-0"
46'-6"
10'-0"
EL. 27.0'
MAX. H.W. EL. 13.5'
EXTREME HIGH T.W. EL. 13.5' (TIDAL GATES LEFT OPEN)
EL. 12.0'
EL. 12.0'
EL. +7.0'
MIN. H.W. EL. 5.0'
EL. 0.0'
NORMAL HIGH T.W. EL. 0.0'
℄ DISTRIBUTOR EL. -9.5'
TRASH RACK GUIDES
EXTREME LOW T.W. EL. -13.0'
DRAFT TUBE GATE SLOT
76'-0"
100'-0"
FLOW
EL. -40.0'
EL. -43.5
ACCESS GALLERY
34'-0"
0 5 10 15 20 25
SCALE - FEET
EL. -65.0'
EL. -83.0'
℄ DRAIN
REVISED 07-20-56
PRELIMINARY
5
4
3
2
1 ORIGINAL ISSUE
ISSUE DESCRIPTION CHKD. INSP. CORR. APPR.
OUTDOOR POWERHOUSE
TYPICAL CROSS SECTION
QUODDY POWER STATION
PASSAMAQUODDY TIDAL POWER DEVELOPMENT
STONE & WEBSTER ENGINEERING CORPORATION
DRAWING NUMBER 9945 HD 012258




| ISSUE | DESCRIPTION | CHKD. | INSP. | CORR. | APPR. |
|---|---|---|---|---|---|
| 5 | | | | | |
| 4 | | | | | |
| 3 | | | | | |
| 2 | | | | | |
| 1 | ORIGINAL ISSUE | | | | |

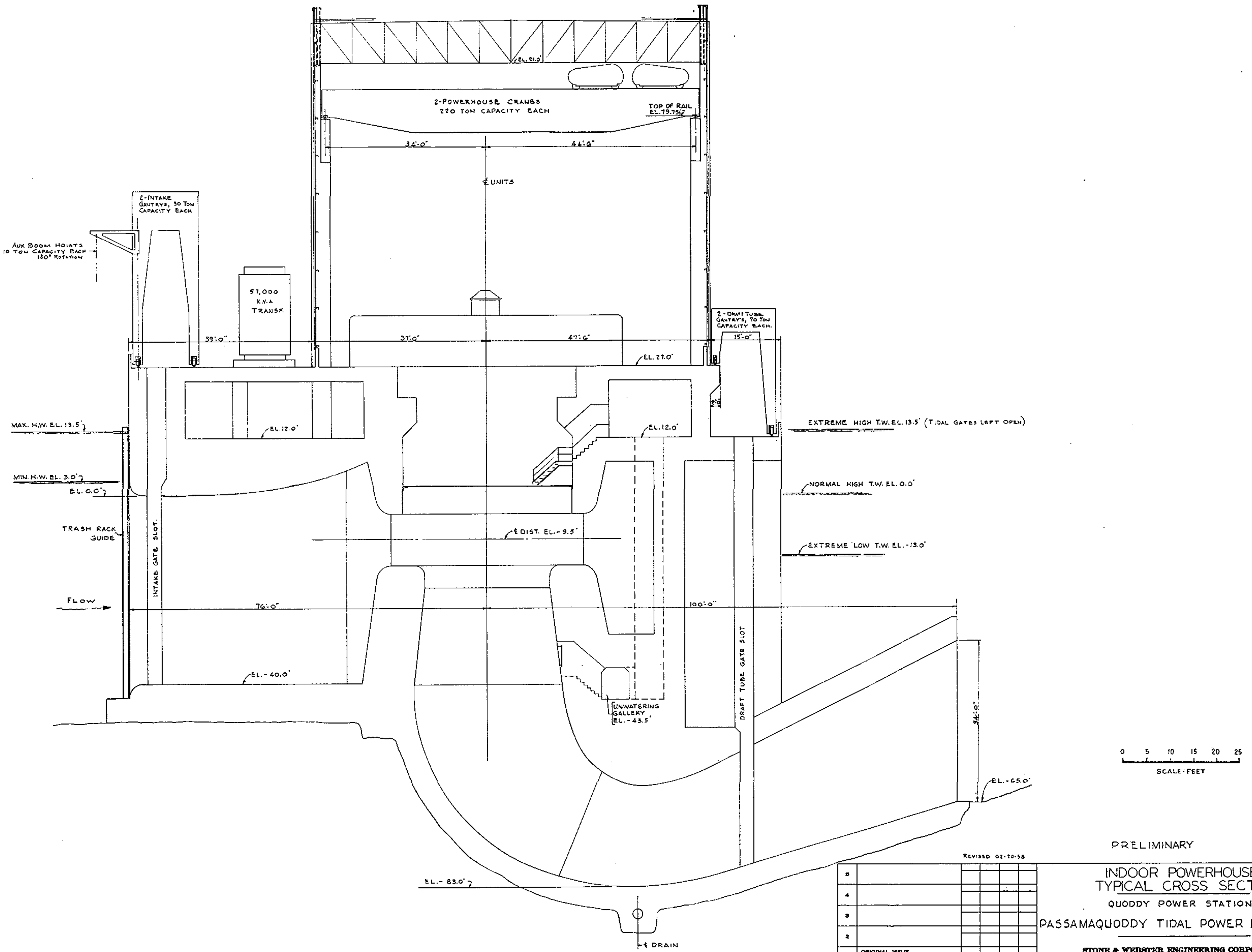
OUTDOOR POWERHOUSE
PLAN- ELEV. 27.0' & ELEV. 12.0'

QUODDY POWER STATION

PASSAMAQUODDY TIDAL POWER DEVELOPMENT

STONE & WEBSTER ENGINEERING CORPORATION

DRAWING NUMBER 9945HD012058




PRELIMINARY

REVISED 02-20-58

| ISSUE | DESCRIPTION | CHKD. | INSP. | CORR. | APPR. |
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| 5 | | | | | |
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| 2 | | | | | |
| 1 | ORIGINAL ISSUE | | | | |

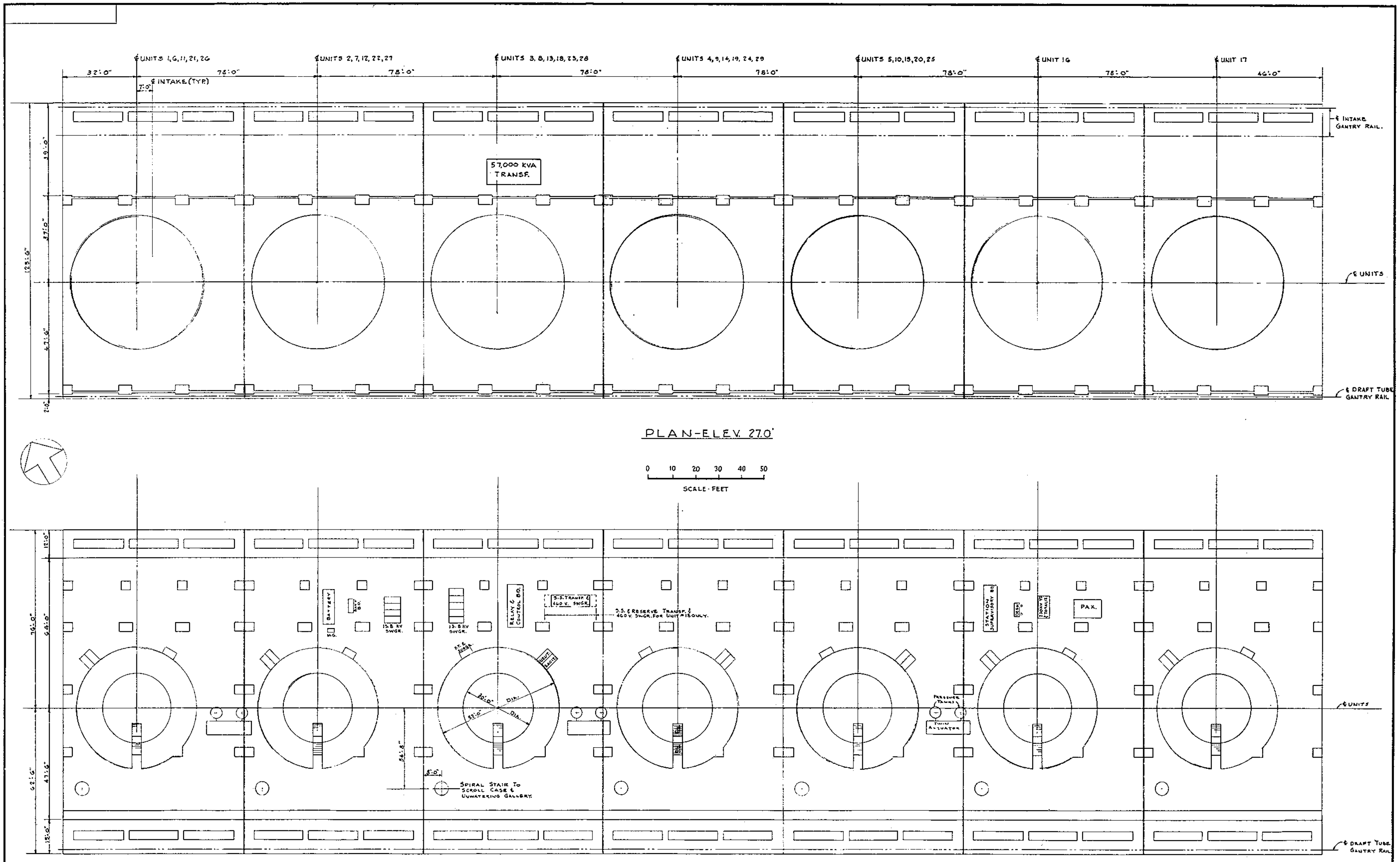
INDOOR POWERHOUSE
TYPICAL CROSS SECTION

QUODDY POWER STATION

PASSAMAQUODDY TIDAL POWER DEVELOPMENT

STONE & WEBSTER ENGINEERING CORPORATION

DRAWING NUMBER 9945 HD 012958




PRELIMINARY

Revised 02-21-58

| ISSUE | DESCRIPTION | CHKD. | INSP. | CORR. | APPR. |
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| 5 | | | | | |
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| 1 | ORIGINAL ISSUE | | | | |

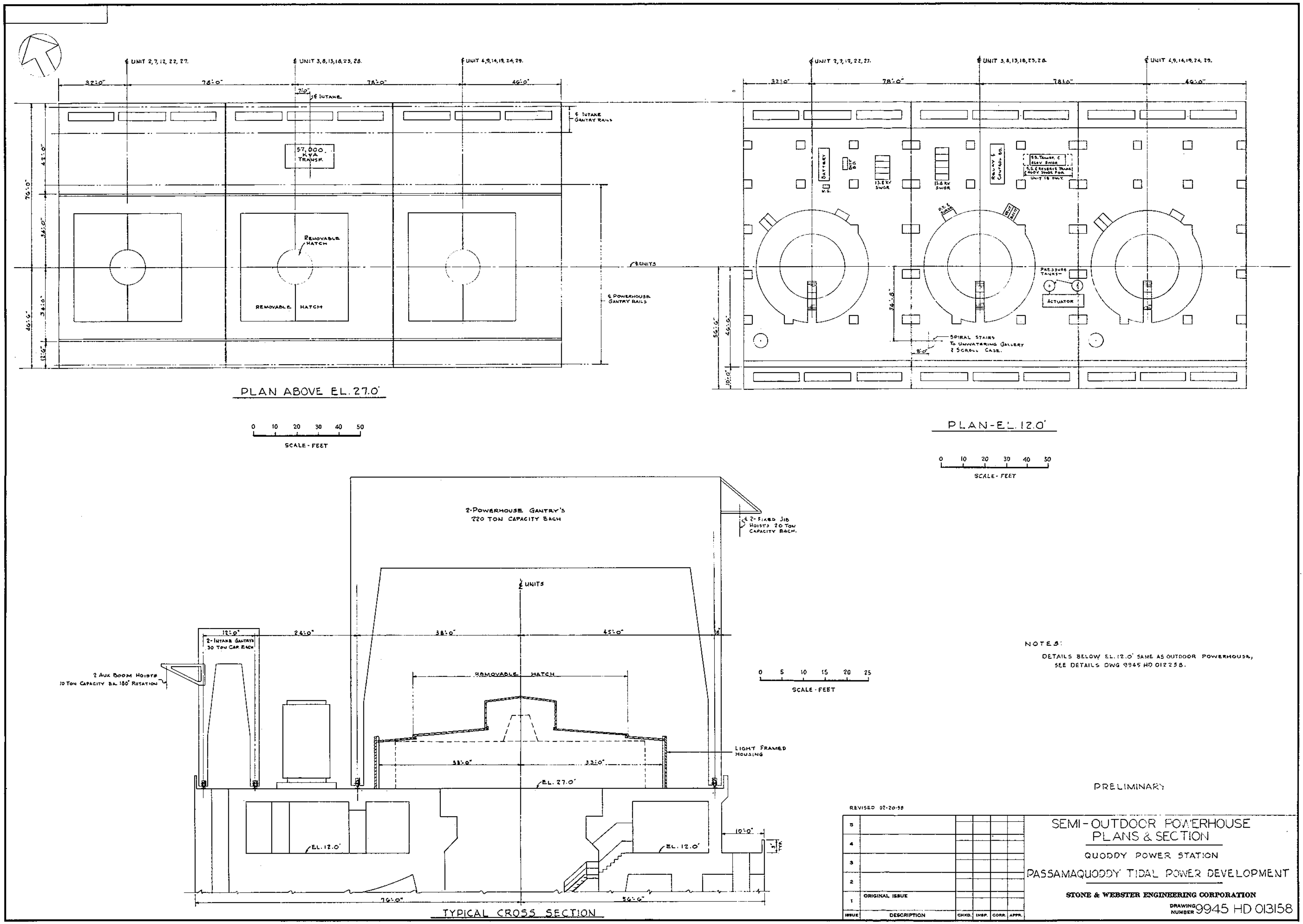
INDOOR POWERHOUSE
PLAN-ELEV. 27.0' & ELEV. 12.0'

QUODDY POWER STATION

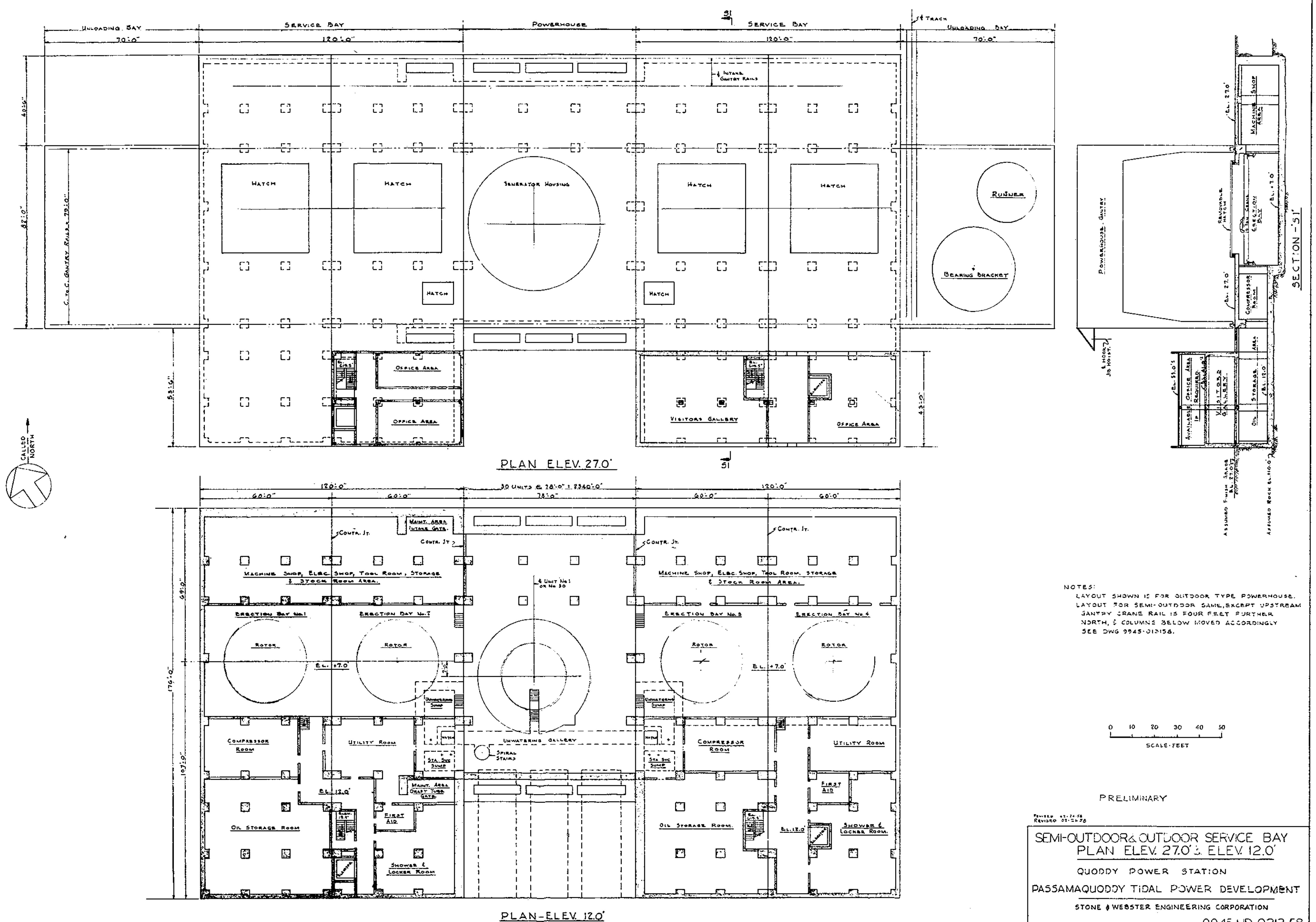
PASSAMAQUODDY TIDAL POWER DEVELOPMENT

STONE & WEBSTER ENGINEERING CORPORATION

DRAWING NUMBER 9945 HD 012758



PLAN ABOVE EL. 27.0'
SCALE - FEET
PLAN - EL. 12.0'
SCALE - FEET
TYPICAL CROSS SECTION
SCALE - FEET
57,000 KVA TRANSF.
REMOVABLE HATCH
REMOVABLE HATCH
2-POWERHOUSE GANTRY'S 220 TON CAPACITY EACH
2-FIXED JIB HOISTS 20 TON CAPACITY EACH.
2-INTAKE GANTRYS 30 TON CAP. EACH
2 AUX BOOM HOISTS 10 TON CAPACITY EA. 180° ROTATION
LIGHT FRAMED HOUSING
EL. 27.0'
EL. 12.0'
BATTERY
RELAY & CONTROL BD.
PRESSURE TANKS
ACTUATOR
SPIRAL STAIRS TO UNWATERING GALLERY & SCROLL CASE.
NOTES:
DETAILS BELOW EL. 12.0' SAME AS OUTDOOR POWERHOUSE, SEE DETAILS DWG 9945 HD 012258.
PRELIMINARY
REVISED 02-20-58
ORIGINAL ISSUE
ISSUE
DESCRIPTION
CHKD.
INSP.
CORR.
APPR.
SEMI-OUTDOOR POWERHOUSE
PLANS & SECTION
QUODDY POWER STATION
PASSAMAQUODDY TIDAL POWER DEVELOPMENT
STONE & WEBSTER ENGINEERING CORPORATION
DRAWING NUMBER 9945 HD 013158




NOTES:
LAYOUT SHOWN IS FOR OUTDOOR TYPE POWERHOUSE.
LAYOUT FOR SEMI-OUTDOOR SAME, EXCEPT UPSTREAM GANTRY CRANE RAIL IS FOUR FEET FURTHER NORTH, & COLUMNS BELOW MOVED ACCORDINGLY SEE DWG 9945-013158.

0 10 20 30 40 50
SCALE-FEET

PRELIMINARY

Revised 02-24-58
Revised 03-24-58

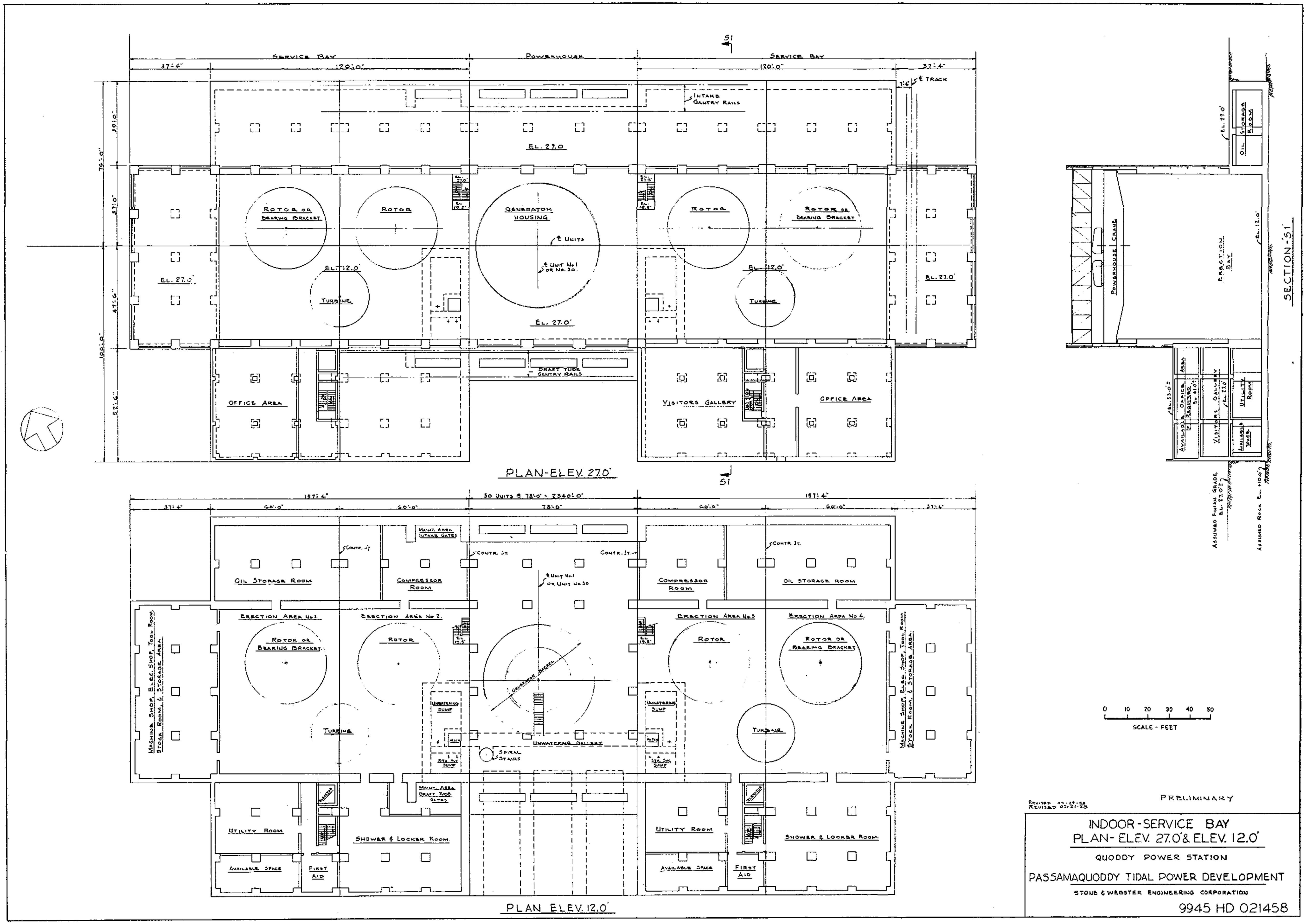
SEMI-OUTDOOR & OUTDOOR SERVICE BAY
PLAN ELEV. 27.0' & ELEV. 12.0'

QUODDY POWER STATION

PASSAMAQUODDY TIDAL POWER DEVELOPMENT

STONE & WEBSTER ENGINEERING CORPORATION

9945 HD 021358



SERVICE BAY
POWERHOUSE
SERVICE BAY
INTAKE GANTRY RAILS
℄ TRACK
EL. 27.0
ROTOR OR BEARING BRACKET
ROTOR
GENERATOR HOUSING
℄ UNITS
℄ UNIT No. 1 OR No. 30
TURBINE
EL. 12.0'
EL. 27.0'
DRAFT TUBE GANTRY RAILS
OFFICE AREA
VISITORS GALLERY
PLAN-ELEV. 27.0'
30 UNITS @ 78'-0" = 2340'-0"
OIL STORAGE ROOM
COMPRESSOR ROOM
MAINT. AREA INTAKE GATES
CONTR. JT.
ERECTION AREA No. 1
ERECTION AREA No. 2
ERECTION AREA No. 3
ERECTION AREA No. 4
GENERATOR BARREL
UNWATERING SUMP
UNWATERING GALLERY
SPIRAL STAIRS
MACHINE SHOP, ELEC. SHOP, TOOL ROOM, STOCK ROOM, & STORAGE AREA
MAINT. AREA DRAFT TUBE GATES
UTILITY ROOM
SHOWER & LOCKER ROOM
AVAILABLE SPACE
FIRST AID
PLAN ELEV. 12.0'
POWERHOUSE CRANE
ERECTION BAY
OIL STORAGE ROOM
AVAILABLE OFFICE AREA IF REQUIRED
VISITORS GALLERY
UTILITY ROOM
ASSUMED FINISH GRADE EL. 27.0'
ASSUMED ROCK EL. +10.0'
SECTION-'S1'
0 10 20 30 40 50
SCALE - FEET
PRELIMINARY
INDOOR-SERVICE BAY
PLAN-ELEV. 27.0' & ELEV. 12.0'
QUODDY POWER STATION
PASSAMAQUODDY TIDAL POWER DEVELOPMENT
STONE & WEBSTER ENGINEERING CORPORATION
9945 HD 021458

NOTES OF CONFERENCE
PASSAMAQUODDY TIDAL POWER PROJECT
CORPS OF ENGINEERS, U.S. ARMY

Held in the Office of
Stone & Webster Engineering Corporation,
Boston, Massachusetts,
on September 27, 1957

Present for:

Corps of Engineers - Messrs. R. D. Field
B. L. Jeter
G. A. Makela

Stone & Webster Engineering Corporation - Messrs. E. L. Blair
W. E. Fisher
B. F. Hall
O. L. Hooper
R. M. Jacobs
G. M. P. Johnson
W. D. Jordan
C. W. Maloney
D. N. McCord
G. R. Strandberg
E. A. Stroberg
R. W. Gunwaldsen

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The purpose of this meeting was to inform Stone & Webster of Corps of Engineers' decisions reached to date that will affect the powerhouse design. At the same time, S&W requested certain information and data, a large part of which will be needed before the design of the powerhouse can begin.

Mr. Field emphasized that the Corps wants the most economical type of power plant with a purely utilitarian type of design.

The Corps has decided on size and speed of hydraulic turbines and the size of water passages. The generators will be 10,000 kw machines plus 15 per cent overload. Information on power factor will be furnished later.

The Corps would like to have S&W help in deciding on the type of generator cooling to be adopted. After some discussion, it was decided that Messrs. Field and Jeter should meet with S&W engineers on September 30 to specifically discuss and decide what the next step should be on this fundamental question. Mr. Field stated that it is standard Corps practice to use $CO_2$

for generator fire protection; however, in view of the unusual type of plant the Quoddy plant will be, he felt that another type of fire protection could be used if there were a good reason for so doing.

Prior to this meeting, S&W prepared a list of information to be supplied by the Corps of Engineers. This list was read and comments made by the Corps' engineers as follows:

1. Results of field and office investigations, such as hydrological, geological, meteorological and any other investigations that are pertinent to the powerhouse design.

   Comment - These will be assembled and forwarded to S&W in the near future.

2. Preliminary designs, maps, plans and other information, already prepared, that would aid in an understanding of how the powerhouse and other elements fit into the overall project.

   Comment - There is not very much information of this type available at this time, but such information as is available will be forwarded to S&W soon.

3. Proposed plant operation. This should include unusual as well as normal operation.

   Comment - This will become apparent from the data to be furnished under the first question.

4. Corps of Engineers standard design criteria.

   Comment - These will be assembled and forwarded to S&W in the near future.

5. Limitations imposed by local conditions.

   Comment - There are no local limitations other than that imposed by weather conditions.

6. Special international questions that would affect powerhouse design, such as Canadian and American control rooms, equipment, personnel, offices, shops, facilities for visitors.

   Comment - The powerhouse will be located in the USA and can be considered as an American project.

7. Data on main unit turbines, generators and governors; including dimensions, weights, costs, spacing of main units. Included should be data on both indoor and outdoor types of generators.

   Comment - These data will soon be available.

8. Data on water passages for turbines.

   Comment - These data are available.

9. Headwater and tailwater elevations. Also maximum heights of waves to be designed for on the upstream and downstream sides of the powerhouse

   Comment - These data are available.

10. Location and capacity of construction plant.

    Comment - Not yet decided.

11. Access to powerhouse during and after construction.

    Comment - Both a road and railroad will be brought to one end of the powerhouse.

12. Location of switchyard, with number and voltage rating of transmission lines.

    Comment - This problem is being studied and the Corps will give S&W this information about the middle of November.

13. Exterior, low voltage, electrical circuits to be supplied from the powerhouse.

    Comment - Same as 12 above.

14. Data on potable water supply.

    Comment - These data are available. It should be noted that the powerhouse will be located near Eastport's water supply pipeline; consequently, fresh water can be brought to the plant.

15. Types of metals to be used where these are subject to wetting by sea water.

    Comment - Being studied at present. Will try to give S&W an answer on this by January 1, 1958.

16. The number of plant personnel for which facilities are to be provided in the powerhouse and what facilities are to be provided.

    <u>Comment</u> - This is not known at present. Personnel will be reduced to a minimum. Automation will be used to the greatest practical extent.

17. The number of visitors for which facilities are to be provided in the powerhouse and what facilities are to be provided.

    <u>Comment</u> - This is not known at present other than that facilities for visitors will be held to a minimum.

18. Does the Corps of Engineers have a prescribed scheduling of unit shutdowns for major maintenance procedures?

    <u>Comment</u> - The Corps engineers will check on this. However, it is doubtful that such a schedule would be applicable to the Quoddy plant since it will be so different from other Corps projects.

19. Does a public highway parallel the powerhouse? If so, on which side of the powerhouse, is it adjacent to the powerhouse, and is it a part of this contract?

    <u>Comment</u> - There will be no public highway on the powerhouse.

20. Are house units required for station service power supply?

    <u>Comment</u> - This will be a part of the S&W assignment; that is, to determine whether there should be house units.

21. Are overhead costs to be included in the cost estimate? If so, what are they?

    <u>Comment</u> - Overhead costs are not to be added to S&W figures except that unit costs will include contractor's overhead and field layout costs. The cost estimate should reflect contractors' bid prices to the Government. It was suggested that Corps and S&W cost men confer on the basis for S&W estimates. Also, it was indicated that the Corps may furnish S&W with unit prices to be used in their part of the project estimate. The cost estimate will reflect prices as of January 1, 1958.

Mr. Field stated that he will make sure that anything the Corps of Engineers furnishes Stone & Webster, even in sketch form, can be considered as final.

# NOTES OF CONFERENCE
# PASSAMAQUODDY TIDAL PROJECT
# CORPS OF ENGINEERS - U.S. ARMY

Held in the office of Stone & Webster Engineering Corporation, September 30, 1957

Present for:

| | | |
|---|---|---|
| Corps of Engineers | - Messrs. | J. Hochgraft<br>W. H. Isaacs<br>B. L. Jeter |
| Stone & Webster Engineering Corporation | - Messrs. | E. L. Blair<br>R. W. Gunwaldsen<br>G. M. P. Johnson<br>C. W. Maloney<br>E. A. Stroberg |

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The meeting was held for the purpose of exchanging ideas on heating, ventilation, fire protection, location of the switchyard, voltage and number of transmission lines and the station service supply system.

## HEATING AND VENTILATION

Methods of heating and ventilating the station were discussed. It was agreed that for the powerhouse, the heating system would depend largely upon the type of generator cooling to be employed. With the probability that the heat release to the air cooling system of the generators under minimum load could be anticipated to be sufficient to maintain a winter heating design temperature suitable for a nonoccupied structure, the heating for the main part of the structure could be from this source only. The type of heating and ventilation for the structure would be developed with studies on the type of generator cooling system to be used.

It was noted that the occupation of the generator floor area would be kept to an absolute minimum. Stone & Webster will make a heat loss study of the hypothetical structure on a unit basis to determine the sufficiency of heating the station by estimated heat release from the generator air cooling system. It was stated that a loss of 300 kw at full load might be expected per unit. The condition for heating the station would, however, be based upon losses occurring during low load.

WATER SUPPLY AND FIRE PROTECTION

It was stated that the Eastport water supply system has a total capacity of 485 gpm and, therefore, has a very limited supply capacity, if any, available for the station. It will be insufficient for supply to the turbine packing glands which, it is estimated by the Corps of Engineers, will require a total of approximately 450 gpm. It was reported that additional service water is available at Boyden Lake, approximately 12 miles northwest of Eastport from which source the Eastport city water is also derived. Delivery of water from Boyden Lake to the powerhouse would necessitate a new supply piping system, including possible pumping and water treatment. Transformer and other water fire protection systems will have to be dependent upon a suitable storage tank supplied from the city water or new auxiliary water system.

LOCATION OF SWITCHYARD

Stone & Webster pointed out that the location of the switchyard would affect the arrangement of transformers and take-off structures on the powerhouse roof and that an agreement on this point is essential for the station layout. After reviewing the relative advantages of locations upstream and downstream, it was agreed to proceed with the switchyard located so that the lines from the powerhouse will take off in the upstream direction.

VOLTAGE AND NUMBER OF TRANSMISSION LINES

The selection of voltage level and the number of transmission lines leaving the switchyard will influence the choice of transformers and, of course, their cost. The Corps advised that this matter will be discussed and determined in a meeting to be held at an early date between the Corps and the Federal Power Commission. The decision made in that meeting will be made known to Stone & Webster without delay.

STATION SERVICE SUPPLY SYSTEM

The discussion of the station service power supply system was necessarily on a general level, since no definite information has as yet been developed on which to base any decisions.

MISCELLANEOUS

The Corps handed Stone & Webster a C&GS map, Sheet 801, showing the geography of the powerhouse site, as well as the several sites for dams. They also gave Stone & Webster one print of their curve sheet Passamaquoddy Power Plant - Mw Output - Average Month, dated September 10, 1957, based on study No. 4-430CUP30110F70EVM dated May 22, 1957. It is understood that this curve, or its equivalent, will be handed to a generator manufacturer as an aid in determining a suitable generator rating on a thermal basis. The curve indicates a useful maximum plant output limit of 345 mw and a monthly minimum of 57 mw. One of the applications of this curve to Stone & Webster work will be in connection with the plant heating system.

# NOTES OF CONFERENCE
# PASSAMAQUODDY TIDAL PROJECT
# CORPS OF ENGINEERS, U. S. ARMY

Held in the office of
Stone & Webster Engineering Corporation
December 12, 1957

Present for:

Corps of Engineers - Messrs. W. Cave
R. D. Field
B. L. Jeter
G. A. Makela

Stone & Webster Engineering Corporation - Messrs. O. L. Hooper
R. M. Jacobs
G. M. P. Johnson
W. D. Jordan
C. W. Maloney
B. M. Rivkin
G. R. Strandberg
E. A. Stroberg
R. W. Gunwaldsen

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The purpose of this meeting was to discuss the electrical and substructural layouts as developed to date by Stone & Webster. Prints of preliminary design sketches were turned over to the Army Engineers. These were:

a. One-Line Wiring Diagram
b. Typical Plan of Electrical Equipment for 6-Unit Grouping
c. Typical Cross-Section of Electrical Equipment for 6-Unit Grouping
d. Plan of Electrical Equipment Between Units 15 and 16
e. Plan of Control Room Between Units 15 and 16
f. Typical Transverse Cross-Section through Center Line of Unit
g. Plan of Scroll Case and Draft Tube Showing Access Galleries

In addition, "Notes on Electrical Design" dated October 31, 1957, describing Stone & Webster preliminary thinking regarding the electrical features of the project were turned over to the Army Engineers. Copies of these notes are attached.

Stone & Webster studies to date have been directed toward developing a layout for an outdoor type of station. Once a satisfactory layout is developed, this layout will be modified to fit a semi-outdoor and indoor type of station.

It is planned to tie the generators together in groups of six units, forming five 6-unit groups. Each group will be served by a 3 phase, forced oil, air-cooled transformer of about 70,000 kva capacity.

Alternate locations for the control room were discussed. The sketch of the control room plan used in the discussions showed the control room located between Units 15 and 16. Other possible locations are at the switchyard end of the powerhouse, on the intake deck near the center of the powerhouse, on the operating floor below the intake deck. Stone & Webster will study these alternatives. There will be need for only one control room since this will be a single operating plant managed jointly by U.S.A. and Canada.

The question of whether the units would be placed in operation in progressive steps or all at about the same time was raised. The Army Engineers have not yet studied this problem in detail; however, Mr. R. D. Field expressed the opinion that all units would probably be placed in operation at about the same time. Stone & Webster will proceed on that basis.

The location of the switchyard and the direction of the high tension lines between transformers and switchyard was briefly discussed. The Army Engineers have studied this problem and concluded that the switchyard will be located near the north end of the powerhouse. The high tension lines will go from transformers on the intake deck to towers in the forebay then northerly to the switchyard.

The preliminary One-Line Wiring Diagram shows the electrical circuits tying in with an outside source for initial start-up of the plant and initial operation of the tide gates. It was decided to carry two cable circuits from the 6-unit 13.8 kv buses to the 13.8 kv yard, also to carry two cables from the 6-unit 13.8 kv buses via the opposite end of the powerhouse to serve the tide gates. In this way, power will be carried to the tide gates from both ends of the powerhouse and will also be available from an outside source for emergency and start-up use.

The cost estimate should include provision for start-up power and for gate operation to control headwater and tail-water pools until power plant has been completed.

Discussion regarding the number and location of erection bays led to the conclusion that two such bays would be required, one at each end of the powerhouse. Two additional temporary bays would probably be required to complete the erection of 30 units in a reasonable length of time. After the plant has been in operation for several years and normal maintenance procedures established, it is anticipated that at times two units will be out simultaneously for major overhaul. In addition, construction of the plant will probably be undertaken from each end. Consequently, two erection bays will be required, also two powerhouse or gantry cranes for handling the units. There should be one well equipped machine shop located in the erection bay at the Eastport end of the plant. Railroad access will probably be from this end, and the powerhouse layout should permit running railroad cars during construction on the intake deck to the other erection bay.

Trash racks will be located on the intake face and stop logs placed in the same supports. It is anticipated that there will be little trash accumulating on the racks, but that which does can be removed by means of an outrigger on the intake gantry crane. Rack bar spacing will probably be about 6"-8" spacing. Maximum discharge through the units will be 8,700 cfs (G.A. Makela) so that maximum velocity through gross intake area will be 4.2 ft per second.

With regard to operation of the plant as head fluctuates with tide, Mr. R. D. Field stated that units would be added to and dropped from the system in groups of three. Also, during annual periods of low tide fluctuation, 10 units will not be used.

General Electric, in submitting estimating prices for the generators (their letter to the Corps of Engineers dated November 19, 1957), quoted a price differential of $15,000 between an indoor and outdoor machine. This appears too low. The Corps of Engineers will check with General Electric on this and also obtain estimating prices from Westinghouse.

The question of sleet affecting plant operation was briefly discussed. As far as is known, utilities in this area have made no provisions for sleet. Mr. R. D. Field stated that he had spent two years in Eastport and had not experienced sleet during this time. Consequently, it was decided that provisions for sleet melting would not be made.

The Corps of Engineers have made a preliminary study of man-power requirements for the plant. It is estimated that each operating shift will require 10 men (1 supervisor, 1 dispatcher, 2 control room, 5 on floor and 1 for switchyard and outside area) or a total of 40 operators. Maintenance personnel will approximately equal the number of operators, and making an allowance for administrative personnel, it appears that the total number of personnel will be about 100.

Locker facilities will be made available to maintenance personnel. About 30 lockers will be provided at each end of the powerhouse in the erection bays. The floor men will have clothing hooks at their stations; control room personnel will have a closet in the control room.

Toilet and shower facilities will be provided in the erection bays. Toilet and wash basin facilities will be provided for floor and control room personnel, one in the control room and one near each 6-unit station. For visitors to the control room area, a minimum of toilet facilities are to be provided; two commodes and two wash basins for women and two commodes, two urinals and two wash basins for men.

With the control room located near the center of the powerhouse, a parking area should be provided near the control room. Also, nominal kitchen facilities will be provided for control room personnel.

Administrative facilities for the entire Quoddy Project are to be provided at the Eastport end of the powerhouse. This may be a separate administration building or an office bay attached to the erection bay. Corps of Engineers studies (W.Cave) have indicated that a separate administration building is more costly than providing an office bay at the end of the powerhouse.

The storage of intake and draft tube gates was discussed. It is anticipated that once normal maintenance procedures for inspection and repair are established, these gates will be in use almost continuously. Consequently, since they will be in the water a great deal of the time, they can be stored in the gate slots when not in use. Three sets of gates are to be provided for the intakes and for the draft tubes. Gate slot covers are to be provided.

Some type of railing will be required on the upstream and downstream edges of the powerhouse. In view of the high waves (8' on the headwater side and 5' on the tailwater side) it was decided that a solid parapet wall would also offer protection to the equipment on the top deck. In addition, light standards can be placed on these walls.

Problems of generator cooling, draft tube unwatering and fire protection were briefly discussed. These problems will be studied in detail by Stone & Webster in the near future.

Mr. W. Cave stated that in recent years, the Corps has found that when the draft tube intermediate piers extend upstream of the draft tube access gallery, the use of mud valves will realize some saving in unwatering systems.

Question was raised as to whether cost estimate should be based on the cost of American equipment or should consider the use of foreign equipment. Mr. R. D. Field will check on this with the Passamaquoddy Board at their next meeting in January.

October 31, 1957

PASSAMAQUODDY
NOTES ON ELECTRICAL DESIGN

Arrange the plant electrically as a structure containing five unit groups, each comprising six generators and one step-up transformer. Service requirements such as unwatering pumps, compressors, lighting, etc., would be on the basis of this six unit grouping.

Start construction of the station in the middle of the ultimate plant.

Station service power requirements which will be in the order of .6% would be supplied through one transformer per six unit group connected to the 13.8 kv bus. Each transformer would be sized to supply one other six unit group in emergencies. One additional station service transformer would be installed at the first group for initial start-up. This transformer would be supplied from an outside source, probably a transformer in the 220 kv switchyard.

Place the control room in the middle of the plant. This control room would be used only as a master control center (or Load Dispatcher's office) using supervisory equipment and telemetering for starting and stopping the units for control of the 220 kv yard and for control of the tide gates.

Assume that normal power to the tide gates will come from a transformer in the 220 kv yard. As a relay for this a 13.8 kv circuit would be provided from the first 13.8 kv unit bus.

Provide one control battery for each six unit group.

Each machine to have neutral air circuit breaker and surge protection.

One neutral resistor or reactor for grounding of each six unit group.

Main Transformers

Assuming generators with .9 pf, a 71,000 kva, 3 phase FOA transformer is required for each six unit group. By the use of 3-winding transformers at no increase in cost, the short circuit requirement for a bus fault will be reduced and 500,000 kva interrupting capacity switchgear will be ample.

There is no advantage physically or economically in using single phase transformers or water-cooled transformers.

Switchgear

The switchgear would be magnetic type air circuit breakers, 15 kv, 500 mva, arranged as draw-out type metalclad switchgear. Generator neutral breakers also would be air circuit breakers in metalclad construction.

The station service switchgear, 460 v, would be arranged in groups, one group for each six unit combination.

Each unit, or each pair of units, would have a governor cabinet which would also include the power center for distribution of 440 v and d-c requirements for each machine.

One control battery with charger and distribution board would be provided for each six unit group.

Control System

The main control room would contain a board for supervisory control and telemetering for each unit; another similar board would be provided for the control and supervision of the 220 kv switchyard. A separate board would be provided for totalizing (by telemetering) the station output. On this board instrumentation is visualized for indication of water levels in the two ponds and automatic or manual control equipment for the tide gates.

In addition to the telephone communication from the unit control panels to the units below, there would be provided in the control room a PAX equipment for general telephone communication as well as the central equipment for loud-speaker communication.

The supervisory control for each unit would include the following points:

1. *
2. Start-Stop
3. Generator Breaker Indication
4. Load Control - Kw
5. Reactive Control - Indication of Local Remote Switch
6. Annunciator
7. Neutral Breaker

*Station check and telephone common for six units.

This equals six control points per machine, or a total of 36 points, and 40-point supervisory equipment for each six unit group is therefore in order. A 48 in. wide duplex panel arranged as a benchboard with telemeter receivers on the upper section is thus required for each six unit group.

At the unit groups one automatic synchronizing equipment would be provided common for six units with transfer relays at each unit.

The station metering is visualized as follows:

Total station kw and total station kvar would be metered and totalized on the panel for this purpose mentioned above.

Each unit would have kw and kvar metering equipment located on the generator panels at the unit group below with transmitters only for these, sending continuously to telemeter indicating equipment on the panels in the control room.

For supervisory control of the 220 kv switchyard it is visualized that a 42-point supervisory equipment is required for control of the breakers and approximately eight points for the tide gate power substation, annunciation, etc. A standard 64-point supervisory group would, therefore, be sufficient, and together with the necessary mimic buses, could be accommodated on a benchboard approximately 8 ft wide.

Telemetering for the yard would probably require kw in or out, kvar in or out, and line volts for each of the four lines. This equipment can readily be accommodated on the 8 ft panel mentioned in the foregoing.

Miscellaneous

The lighting system would be supplied from the 440 v group buses with the 440 v feeders overlapping adjacent group areas and small transformers provided at the lighting load centers. The 440 v feeders would require induction voltage regulators at the sources.

A minimum of d-c emergency lighting is visualized. Such d-c lighting would be limited to the main control room, the governor panels, the wheel pits and similar spots of vital importance.

The five station service supply systems are arranged for a complete relay, one from the other. In view of the unusual characteristics of this plan some may think that this does not provide sufficient power for maintenance and lighting. Should this thought prevail an additional portable supply could readily be arranged in the form of a trailer-mounted generating unit with a capacity sufficient for lighting and minor power requirements of a six unit group. This trailer-mounted unit would be provided with cables for plug-in connections to each six unit 460 v bus.

# NOTES OF CONFERENCE
# PASSAMAQUODDY TIDAL POWER PROJECT
# CORPS OF ENGINEERS, U. S. ARMY

Held in the office of
Stone & Webster Engineering Corporation
on February 27, 1958

Present for:

| | | |
|---|---|---|
| Corps of Engineers | - Messrs. | W. Cave<br>R. D. Field<br>B. L. Jeter<br>G. A. Makela<br>A. C. Stewart |
| Stone & Webster Engineering Corporation | - Messrs. | O. L. Hooper<br>R. M. Jacobs<br>G. M. P. Johnson<br>J. J. Kennedy<br>D. N. McCord<br>R. R. Peatfield<br>B. M. Rivkin<br>G. W. Saunders<br>G. R. Strandberg<br>E. A. Stroberg<br>R. W. Gunwaldsen |

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The purpose of this meeting was to review layouts of outdoor, semi-outdoor and indoor types of powerhouse and their cost differentials in order to decide on the type of powerhouse and general equipment arrangement to be adopted at Passamaquoddy. The following drawings served as a basis for the discussions:

HD012258 - Outdoor Powerhouse - Typical Cross Section
HD012058 - Outdoor Powerhouse Plan - Elev. 27.0 & Elev. 12.0
HD012958 - Indoor Powerhouse - Typical Cross Section
HD012758 - Indoor Powerhouse Plan - Elev. 27.0 & Elev. 12.0
HD013158 - Semi-Outdoor Powerhouse - Plans and Section
HD021358 - Semi-Outdoor & Outdoor Service Bay Plan - Elev. 27.0 & Elev. 12.0
HD021458 - Indoor Service Bay Plan - Elev. 27.0 & Elev. 12.0

Two prints of each drawing were turned over to the Army Engineers.

All powerhouse designs were based on similar equipment layouts for 30 - 10,000 kw units as follows: units tied together electrically in groups of five, with one operating center and one 57,000 kva transformer for each five units; transformers located on intake deck, an ideal location in terms of powerhouse cost, proximity to generators and electrical control equipment, and direction for take-off of overhead transmission lines to switchyard; erection and service bays provided at both ends of the powerhouse; control room located near the center of the powerhouse on the El. 12.0 level; and equipment rooms and offices located adjacent to the service bays with the major portion of office space being located at the south (Eastport) end of the powerhouse.

Because of the high turbine setting with respect to tailwater, the large physical size of the units and the moderate fluctuations in water levels, the generators will be set well above maximum high water level. For this reason, the site lends itself particularly well to the outdoor type.

In all three types, width of powerhouse has been determined by equipment space requirements at the El. 12.0 level. Width of intake deck has been set by space requirements for electrical equipment and control cable gallery; similarly, width of downstream deck by space requirements for piping gallery and access to scroll case. With the units tied together electrically in groups of five, the electrical equipment for operation, control and protection of five units will occupy only two bays of each five bay group. Consequently, space in the adjoining three bays is available for other equipment -- in the case of Bay No. 16, for the control room. Twin governor actuator cabinets have been adopted to provide space between every other unit to tie mechanical equipment under the intake deck with piping in the gallery along the downstream wall.

Consequently, the layouts of the three types of powerhouses, below the El. 27.0 level, are essentially the same. The outdoor and semi-outdoor station layouts are identical. In the case of the indoor station, the draft tube deck and supporting piers have been enlarged to accommodate a draft tube gantry crane; in addition, walls and piers supporting superstructure columns have been enlarged to carry the heavy column loads.

Therefore, the real difference in the three types is the treatment of the plant above the El. 27.0 level. In the case of the outdoor station, circular housings with removable circular hatches have been adopted. This design is simple, strictly utilitarian but involves additional cost for weatherproofing the generators and protecting them during erection. A continuous light-framed housing over the 30 generators with powerhouse gantry cranes straddling the housing has been adopted for the semi-outdoor station. Removable rectangular hatches would be located over each unit. Since the generators would be inside the housing, no weatherproofing is required; however, additional costs would be incurred during erection. Finally, a typical indoor station with superstructure housing the overhead bridge cranes as well as the units was included in the comparison.

To compare fully the various powerhouse types, consideration has been given to the layout of the service bays. In general, the upstream area at El. 27.0 level has been kept free for access to the power plant intake deck, the ends of the service bays have been kept free to enable the Contractor to provide (should he so desire) additional temporary erection facilities that can be reached by the powerhouse cranes, and the downstream area at El. 27.0 level allocated for office space and visitors' facilities.

In the case of the semi-outdoor station, there is no advantage in extending the light-framed housing over the service bays. Therefore the service bay layout developed for the outdoor powerhouse has been used for the semi-outdoor powerhouse.

Because all 30 units will go into operation at about the same time, time required for powerhouse construction should be held to a minimum. This, in turn, will require that several units be assembled and erected simultaneously. Therefore, while space has been provided for the servicing of one unit in each service bay, enclosed areas for the assembly of two rotors in each bay have been provided. This will permit, during construction, four units to be assembled at one time -- four rotors in the enclosed areas and four bearing brackets and four turbines in adjoining unenclosed areas.

It is planned that the powerhouse gantry cranes be "housed-in". This will provide considerable protection against inclement weather when hatches over either the units or the service bays are open.

All gantry cranes will be self-propelled by providing them with gasoline or diesel generator sets. This will eliminate the costly collector systems and the troublesome problem of protecting them against salty atmosphere.

Following this general explanation of the approach followed in developing the layouts of the three types of stations, a tabulation of "Estimated Difference in Powerhouse Costs" dated February 26, 1958, was presented. A copy is attached.

This tabulation shows the outdoor station to be the most economical type of powerhouse. Incremental costs for the other two types would be about:

| | |
|---|---|
| Semi-outdoor | $800,000 |
| Indoor | 2,500,000 |

It was explained that in estimating the cost of the superstructure for the indoor and semi-outdoor stations, a minimum type of siding and roofing was assumed (Robertson's 24 gage V-beam Galbestos siding and 14 gage long-span Q-decking). If a more durable type of siding is required, the spread in cost differentials will be correspondingly greater. Messrs. W. Cave and R. D. Field expressed doubt that the Corps of Engineers would agree to the use of any siding with less than 50-year life. It was their opinion that concrete would probably be used. Therefore the cost differentials can be expected to be considerably larger than those listed above.

The semi-outdoor station was quickly eliminated from further consideration because it has no significant advantage over the outdoor station and would be more costly.

In view of the very large difference in cost between the indoor and outdoor type of powerhouses and the fact that the "housed-in" gantry will afford considerable protection to the units, decision was reached to adopt the outdoor type powerhouse at Passamaquoddy.

Following this there was considerable discussion on the possibility of using Oilostatic cables instead of overhead transmission cables to the switchyard in order to avoid the need for expensive tower foundations in the head-race channel. The outcome of these discussions was to group the units together electrically in two groups of 7 units and two groups of 8 units, so that there will be four transformers and four Oilostatic cables. In the event this new arrangement requires air circuit breakers in excess of 750,000 kva, this decision will have to be reviewed because going to the larger capacity air circuit breakers will necessitate going to compressed air circuit breakers which require considerably greater space than has been allocated for this equipment. Stone & Webster will also check on the space requirements for the larger transformers.

Stone & Webster will prepare a letter of recommendation on the type of plant to be adopted. Included with this letter will be copies of the drawings discussed at this conference.

Stone & Webster will now prepare design memoranda covering various phases of the powerhouse design, such as: station service, fire protection of units, generator cooling, air and oil service, etc.

During the course of the conference, a number of items were briefly touched upon. These are:

1. Isolating switch at the powerhouse side of the transmission line can be eliminated.

2. In view of the salty atmosphere, enclosed generators should be used to provide maximum protection and reduce maintenance.

3. Consideration should be given to the problem of snow removal.

4. With Oilostatic cable arrangement, reduce minimum clearance between transformer and intake gantry crane leg from 5 ft to 3 ft.

5. Stone & Webster are not to include excavation costs in their cost estimate; the Army Engineers will include this item in their estimate.

6. Transmission voltage will be:
   Canadian: 138,000 kv
   American: 230,000 kv

7. Pumping equipment for Oilostatic cables is to be located in service bay at north end.

8. Gates and racks will be provided with cathodic protection. Army Engineers have not yet reached decision on how to provide turbines with protection against salt water corrosion.

9. General Electric have advised against introducing salt water in the generators for cooling. They are writing to Stone & Webster to confirm this.

10. Minimum capacity of the Passamaquoddy Plant will be 75,000 kw. This could be continuous for 75 hr and should be a consideration in designing the heating and ventilating system.

11. Transformer oil will be handled by means of portable equipment.

12. Common oil will be used for unit bearings and governor oil pressure system.

STONE & WEBSTER ENGINEERING CORPORATION

February 26, 1958

PRELIMINARY

PASSAMAQUODDY TIDAL POWER PROJECT
ESTIMATED DIFFERENCE IN POWERHOUSE CONSTRUCTION COSTS

| | Type of Powerhouse | | |
|---|---|---|---|
| | Indoor | Semi-Outdoor | Outdoor |
| **EACH UNIT BAY** | | | |
| Superstructure | $99,000 | $45,000 | $1,000 |
| Generator Housing | - | - | 15,000 |
| Generator Erection | - | 10,000 | 15,000 |
| Concrete Parapet Walls | - | 2,000 | 2,000 |
| Concrete below El. 27.0 | 9,000 | - | - |
| TOTAL | $108,000 | $57,000 | $33,000 |
| **ENTIRE POWERHOUSE** | | | |
| Unit Bays (30) | $3,240,000 | $1,710,000 | $990,000 |
| Service Bays (2) | 500,000 | 210,000 | 210,000 |
| Heating & Ventilating | 380,000 | 40,000 | - |
| Powerhouse Cranes (2) | 380,000 | 860,000 | 850,000 |
| Draft Tube Cranes (2) | 50,000 | - | - |
| Service Bay Cranes (2) | - | 30,000 | 30,000 |
| TOTAL | $4,550,000 | $2,850,000 | $2,080,000 |
| COST DIFFERENTIAL | $2,470,000 | $770,000 | BASE |

Note: These figures do not include indirect and overhead costs and, therefore, are not directly comparable to the figures included in the detailed cost estimate given in Table 3.

(Added June 30, 1958)

NOTES OF CONFERENCE
PASSAMAQUODDY TIDAL POWER PROJECT
CORPS OF ENGINEERS, U.S. ARMY

Held in the Office of
Stone & Webster Engineering Corporation
on April 14 and 18, 1958

Present for:

| | | |
|---|---|---|
| Corps of Engineers | - Messrs. | R. D. Field |
| | | B. L. Jeter |
| | | W. H. Isaacs |
| | | J. Hochgraft |
| Stone & Webster Engineering Corporation | - Messrs. | E. L. Blair* |
| | | A. W. Huckins* |
| | | R. M. Jacobs* |
| | | J. J. Kennedy* |
| | | C. W. Maloney* |
| | | B. M. Rivkin |
| | | E. A. Stroberg |
| | | R. W. Gunwaldsen |

*Part time

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The purpose of these meetings was to discuss memoranda covering the design of various systems and equipment to be included in the powerhouse. These memoranda were those forwarded to the Corps of Engineers with letters dated March 28 and April 4, 1958.

As a result of these discussions, modifications to the proposed designs have been agreed to and these changes are noted in the notes that follow.

## ARCHITECTURAL-STRUCTURAL

The structures at each end of the powerhouse, which contain the offices and visitors' gallery, will be constructed of reinforced concrete, rather than face brick backed up by 8 in. concrete block.

Glazed architect-style tile will be used, rather than unglazed buff tile, where specified for interior walls.

## HYDRAULIC

### HYD-NO. 1

Concrete and reinforced concrete design will follow, in general, the recommendations contained in the Building Code Requirements for Reinforced Concrete (ACI 318-57) where they do not conflict with the above noted Engineering Manual.

### HYD-NO. 2

Because fresh water supply is limited and costly, turbine packing glands will be designed to operate without the use of water. Turbine manufacturers report that this can be done. One manufacturer stated that on recent designs they are using a grease packed box, lubricated periodically by the centralized lubrication system; favorable reports have been received from the field.

Runaway speed will be approximately 100 rpm.

### HYD-NO. 3

#### Intake Gates

For emergency closure, slide gates will be dropped in the two outside water passageways and then a wheel gate will be dropped into the middle passageway. With this type of operation, the severest requirement for closure will occur, if turbine wicket gates are wide open, when the upper section of a slide gate is just closing the second passageway. Under these conditions, the upper gate section will close under its own weight whenever the gross head on the plant is less than 23 ft.

To prevent marine growth on the gate guides, these guides will be painted with an antifouling paint.

#### Draft Tube Gates

To rewater the draft tubes, water will be admitted to the unwatered draft tube by drawing water from an operating draft tube through the unwatering header.

### HYD-NO. 4

A rotating jib crane will be provided on the downstream side of each powerhouse gantry crane, rather than a fixed jib crane.

Diesel generator set on powerhouse gantry crane will be 200 kw, rather than 150.

Generator set on each intake gantry crane will be provided with a diesel engine, rather than gasoline.

## BUILDING SERVICE

### BS-NO. 1 - GENERATOR COOLING SYSTEM

This memorandum will be revised.

### BS-NO. 2 - STATION HEATING SYSTEMS

This memorandum will be revised.

### BS-NO. 3 - STATION VENTILATION SYSTEMS

Owing to changes in station heating systems, this memorandum will be revised to conform with the changes to the heating system. Provision for winter ventilation will be included.

### BS-NO. 4 - FIRE PROTECTION SYSTEMS

50,000 gal, rather than 120,000 gal, of water storage will be required for transformer fire protection. However, a water storage tank of 125,000 gal capacity will be provided, since a tank of this size will be required to satisfy estimated construction water requirements. (R. D. Field telephone conversation with R. W. Gunwaldsen April 21.) Consequently, such a storage volume will be more than ample for fire protection.

A recheck of the fire main indicates that a 12 in. header, rather than 16 in., will be provided.

All interior hose stations on the operating floor will be deleted and $CO_2$ hand extinguishers will be substituted. Six exterior hose stations will be added, one in the vicinity of each transformer and one in each service bay.

Five, rather than three, generators will be connected to each $CO_2$ fire protection system. One unconnected spare bank of $CO_2$ cylinders will be provided.

BS-NO. 5 - OIL SYSTEMS

Delete turbine guide bearing service pump. Reduce capacity of centrifuge type oil purifier from 1,800 gph to 1,200 gph. East service bay centrifuge will be permanently installed and centrifuge in west service bay will be portable so as to service the switchyard.

Delete the manufacturer's name (Bowser type) from filter press and paper drying oven.

BS-NO. 6 - COMPRESSED AIR SYSTEMS

For each 15 units provide two 50 hp compressors, rather than one 100 hp compressor.

Delete 20 hp compressor for make-up service.

Air cooled intercoolers and water cooled aftercoolers will be provided.

Delete note calling for pressure reducing equipment at all governors.

BS-NO. 7 - POWERHOUSE DRAINAGE SYSTEMS

An interconnection between the drainage sump and the unwatering sump will be provided. This interconnection will be provided with check and shutoff valves.

One 500 gpm drainage pump will be provided at each sump, rather than one 1,000 gpm pump.

BS-NO. 8 - UNWATERING SYSTEM

Reduce capacity of unwatering pumps from 10,000 gpm to 5,000 gpm. This will require three hours to unwater a draft tube with two pumps operating and six hours with one pump operating.

BS-NO. 9 - PLUMBING SYSTEMS

No changes.

BS-NO. 10 - SALT WATER SYSTEM

A salt water system will no longer be required because turbine packing gland will be designed to use a grease packed box, requiring no water.

BS-NO. 11 - DECK WASHING AND SNOW REMOVAL SYSTEMS

For deck washdown facilities, exterior fire protection hose stations will be used. Therefore, hose valve outlets connected by 1 1/2 in. branches to the fire main will not be required.

BS-NO. 12 - TRANSFORMER PIT DRAINAGE

Pits filled with crushed rock will be provided under each transformer. Pit drainage of water and/or oil will be discharged to the tailwater side of the powerhouse.

BS-NO. 13 - WATER LEVEL RECORDING EQUIPMENT

One stilling well, rather than two, will be provided for headwater level recording and one stilling well, rather than two, for tailwater level recording. These will be located in the east service bay.

BS-NO. 14 - MACHINE SHOP EQUIPMENT

This will be called maintenance shop, rather than machine shop.

Gate repairing will be done in the west erection bay.

A forge will be added in the east maintenance shop.

## ELECTRICAL

ELEC-NO. 1 - GENERAL

No changes.

ELEC-NO. 2 - MAIN TRANSFORMERS

No changes.

ELEC-NO. 3 - 13.8 KV SWITCHGEAR

Copies of computations for circuit breaker duty will be furnished. Consideration will be given to using segregated phase type bus ties and isolated phase risers to the transformers.

ELEC-NO. 4 - CONTROL STORAGE BATTERIES

No changes.

ELEC-NO. 5 - EXCITATION SYSTEMS

No changes.

ELEC-NO. 6 - NEUTRAL GROUNDING AND SURGE PROTECTION

Copies of computations for neutral ground will be furnished.

ELEC-NO. 7 - STATION SERVICE SYSTEM

The station service transformers will be sized on the basis of motor lists which are now being revised to conform with changes made in the Building Service memoranda.

The start-up transformer will be provided, but not connected; i.e., it will be a spare unit.

Interrupting capacity of 460 v switchgear will be reviewed when transformers have been sized.

ELEC-NO. 8 - CONTROL SYSTEMS

A point will be added in the supervisory system to permit partial start; i.e., bring unit up to speed without completion of synchronizing.

ELEC-NO. 9 - PROTECTIVE RELAYS

The Corps of Engineers referred to Plate II of the Engineering Manual for their practice in protective relaying. It was also pointed out that the Corps uses a ground relay in addition to the generator differential relays.

A ground relay will be provided in the 13.8 kv feeder circuits.

Consideration should be given to combining the bus differential relaying with the transformer differential relaying.

ELEC-NO. 10 - COMMUNICATION SYSTEMS

No separate paging system will be provided, but a code call system will be made a part of the PAX system.

ELEC-NO. 11 - STATION LIGHTING

No changes.

ELEC-NO. 12 - RACEWAYS AND CONDUCTORS

No changes.

ELEC-NO. 13 - GROUND SYSTEM

No changes.

ELEC-NO. 14 - CATHODIC PROTECTION

No changes.

# NOTES OF CONFERENCE
# PASSAMAQUODDY TIDAL POWER PROJECT
# CORPS OF ENGINEERS

Held in the Office of
Corps of Engineers
May 9, 1958

Present for:

| | | |
|---|---|---|
| Corps of Engineers | - Messrs. | R. D. Field |
| | | G. A. Makela |
| | | W. O. Wilcox |
| | | H. C. Crandall |
| | | A. C. Stewart |
| Stone & Webster Engineering Corporation | - Messrs. | B. M. Rivkin |
| | | G. W. Saunders |
| | | R. W. Gunwaldsen |

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The purpose of this meeting was to discuss the setup of unit cost figures to be used in the cost estimate of the powerhouse and other factors influencing the estimate.

It was agreed that the Corps of Engineers would furnish by mid-week standards to be used by Stone & Webster Engineering Corporation as a guide in setting up unit costs. The standards will include a list of those items to be included in the Direct Costs and will give percentages to be applied to the Direct Costs to obtain contractors' bid prices.

The cost estimate to be prepared by Stone & Webster will reflect a contractor's bid price. Contingencies for uncertain field conditions and changes in design will not be included in the Stone & Webster estimate; such contingencies will be added by the Corps at the time they prepare their estimate for the entire project. However, contingencies for limitations in setting up the estimate, such as quantity take-off or equipment pricing, will be included with Stone & Webster unit cost figures - as a contractor would normally do.

The Corps have not yet determined the price of aggregate; but for the purposes of the Stone & Webster estimate, aggregate on the stockpile will be assumed at $3.00/ton. If the price finally determined is other than $3.00, the Corps, when preparing their estimate for the over-all project, will adjust the Stone & Webster estimate a corresponding amount.

The cost of fresh water will not be included in the Stone & Webster estimate.

The Corps will furnish Stone & Webster estimated prices for the generators and turbines with governors. The generator price will include installation costs, while the turbine and governor price will not.

# NOTES OF CONFERENCE
# PASSAMAQUODDY TIDAL POWER PROJECT
# CORPS OF ENGINEERS

Held in the office of
Stone & Webster Engineering Corporation
on May 23, 1958

Present for:

Corps of Engineers - Messrs. B. L. Jeter
J. Hochgraft
W. H. Isaacs

Stone & Webster Engineering Corporation - Messrs. E. L. Blair
R. W. Gunwaldsen
G. M. P. Johnson

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The purpose of this meeting was to review the revised memoranda covering the design of the generator cooling system, station heating and station ventilation systems, which have been forwarded to the Corps of Engineers with letter dated May 19, 1958.

After discussions, further modifications to the proposed designs were agreed upon as follows:

## BUILDING SERVICE

### BS-NO. 1 - GENERATOR COOLING SYSTEM

A single supply and return cooling water connection will be provided to each generator unit, serving a single cooling ring within the generator, rather than two connections each serving a half ring with the generator. The generator cooling water discharge line will include a modulating valve, thermostatically controlled, to maintain a uniform temperature of the generator windings under varying load conditions. It was explained that the parameter of 86 F water in and 91 F water out of the generator cooling coils was based upon information received from the generator manufacturer whose proposal had been used for the purpose of making a report. Selection of this temperature level would in addition be more favorable to the station heating system than a lower temperature range. It should be regarded as a maximum condition and heat exchangers have been estimated upon this basis.

The jackets and headers of heat exchangers will be neoprene coated. Similar neoprene coating will be applied to inside surfaces of all salt water supply and discharge piping to the heat exchangers. A minimum of this piping should be embedded in mass concrete.

The supply and return cooling water headers will be sectionalized into four sections with gate valves to enable repairs or leaks to be isolated. A cooling water make-up line will be provided from the make-up surge tank connecting separately to each section of the cooling water supply header.

A relief line from the cooling water supply header to the return header will be provided in each section of the headers to prevent excessive pressures occuring in the cooling system whenever a unit may shut down or the cooling system otherwise modulate.

The thrust bearing cooling water will be drawn from the 86 F generator cooling water supply system. The machine will be designed to use this temperature water in the thrust bearing cooling system.

BS-NO. 2 - STATION HEATING SYSTEMS

Mr. Jeter asked why we had adopted electric heating for tempering make-up outside air for the ventilation of the service bays, rather than heating this air by hot water coils supplied from the generator cooling water return header. It was explained that with this low temperature water there would be considerable danger of freezing coils and for this reason it was considered inadvisable to use a hot water tempering system.

Electric heating will be retained for tempering the intake air.

BS-NO. 3 - STATION VENTILATION SYSTEMS

There were no comments regarding this revised memorandum.

# NOTES OF CONFERENCE
# PASSAMAQUODDY TIDAL POWER PROJECT
# CORPS OF ENGINEERS

Held in the office of
Stone & Webster Engineering Corporation
on June 10, 1958

Present for:

Corps of Engineers - Messrs. W. Cave
R. D. Field
B. L. Jeter
G. A. Makela

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The purpose of this meeting was to discuss a draft of the Preliminary Design Report, the cost estimate and the drawings that will accompany the report.

As a result of these discussions, modifications to the report, cost estimate and drawings have been agreed to and these changes are noted in the notes that follow.

## DRAWINGS

### DRAWING 001 - "GENERAL ARRANGEMENT"

1 - Move transfer car concrete slab from west unloading bay to east unloading bay.

2 - Remove that part of transfer car track shown in west unloading bay normal to axis of plant.

3 - Show location of roof ventilators.

DRAWING 002 - "TYPICAL CROSS SECTION"

1 - Interchange locations of draft tube access gallery and vertical stair wells so as to provide maximum clearance between floor of scroll case and ceiling of access gallery.

2 - Show structural frame around transformer.

3 - Modify picture of scroll case drain by deleting vertical bend in vicinity of stairs leading to draft tube manhole.

4 - Show waterproof membrane and wearing surface on cross section.

DRAWING 003 - "PLAN - OPERATING FLOOR"

1 - Show access from spiral stair well to scroll case.

2 - Show another stairway through concrete barrel to turbine pit.

3 - Interchange locations of draft tube access gallery and vertical stair wells.

4 - Show location of motor control centers.

5 - Move vertical stair well to other side of each generator bay.

6 - Show kitchen in each group control room.

DRAWING 004 - "PLANS - SERVICE BAYS"

1 - Show toilet areas.

2 - Some door openings appear narrow; this to be checked.

3 - Change "Available office area if required" to "Office area".

4 - Remove certain walls in each service bay (as per marked print), substituting in some cases wire screen.

5 - Eliminate gate repair area and shift oil room - Oilostatic cables into that area.

6 - Show start of cable tunnel to switchyard.

7 - Shift concrete slab from west unloading bay to east unloading bay.

DRAWING 005 - "MAIN ONE LINE DIAGRAM"

1 - Some of the relaying and metering functions shown, which are in line with Stone & Webster current practice for this size of generating units, differ from the standards of the Corps of Engineers. Stone & Webster agreed to revise its drawings to conform with the practice of the Corps. The principal change is a combination of the bus differential and the transformer differential relaying into one set of relays and the use of one relay in the generator neutral ground. A number of indicating instruments were also added. A current transformer should be provided on the transformer neutral bushing. This transformer will be used for line relaying.

2 - It was agreed to provide two neutral breakers for each group of generators; only one of which will be closed at a time.

3 - Watthour meters should be provided in the station service and 13.8 kv feeder circuits.

4 - The Corps suggested the use of 14,400-120 v potential transformers instead of 13,800-120 v and the use of 13,800 v as primary voltage on the station service transformers rather than 13,200 v.

5 - The Corps expressed preference for a neutral ground resistor to limit ground current to about 1.5 times full load current. A standard 10 ohm resistor will, therefore, be used rather than the 4 ohm resistor now shown.

DRAWING 006 - "480 V ONE LINE DIAGRAM"

1 - Use designation "Thrust" bearing rather than "Kingsbury" bearing.

2 - Provide an oil pump for jacking up the generator rotor.

3 - Provide turbine bearing oil pumps; one a-c and one d-c.

4 - Provide a grease pump motor for the packing gland on each unit.

5 - Pump for return of dirty oil from thrust bearings and guide bearings will be portable.

6 - There will be no elevator in the west side service area.

7 - Add the 36 kw heaters required in the east and west service area oil purifiers.

8 - Show 25 kw heaters which will be permanent part of the generators.

9 - Change the guide bearing oil pumps to dirty lubricating oil transfer pumps.

10 - Show a different symbol for the main transformer fans and pumps.

DRAWING 009 - "CONTROL EQUIPMENT ARRANGEMENT"

1 - Include those items shown on print marked by Corps of Engineers.

2 - Show elevations of relay panels.

3 - Show voltage regulator element in Section DD.

DRAWING 007 - "MAIN TRANSFORMER ARRANGEMENT"

1 - Show main transformer neutral bushing (110 kw BIL) and complete picture of lightning arrester mounting.

DRAWING 008 - "CABLE TRAY ARRANGEMENT"

1 - Indicate the Oilostatic cables in Sections AA and BB.

2 - Show motor control centers and neutral resistor.

DRAWING 010 - "PIPING CONNECTIONS AT GENERATORS"

1 - The Corps of Engineers felt that the 20 in. cooling water headers were too large; it was agreed that this would be checked. (Subsequent check revealed that the design was based on a maximum flow of 4,800 gpm at a design velocity of 5-6 fps. Consequently, the 20 in. size is satisfactory. However, it was found that at the ends of the headers, where the maximum flow is 2,400 gpm, the size may be reduced and this change will be made on the drawing.)

2 - Vacuum pumps will be provided on each salt water heat exchanger piping system.

3 - A portable pump will be provided to pump turbine guide bearing oil and thrust bearing oil to the dirty oil tanks.

DRAWING 011 - "PIPING AND EQUIPMENT ARRANGEMENT"

1 - Piping headers will be sectionalized.

DRAWING 012 - "EQUIPMENT ARRANGEMENT - EAST SERVICE BAY"

1 - Remove certain walls in accordance with notes under Drawing 004.

2 - Toilet and locker room details are to be shown on the general drawings rather than this drawing.

DRAWING 013 - "EQUIPMENT ARRANGEMENT - WEST SERVICE BAY"

1 - Remove certain walls in accordance with notes under Drawing 004.

2 - The Corps of Engineers was of the opinion that air receivers were too small; it was agreed this would be checked. (As a result of subsequent check, the 100 psi receiver will be increased from 100 to 200 cu ft and the 300 psi receiver from 11 to 30 cu ft.)

DRAWING 014 - "MISCELLANEOUS PIPING SECTIONS"

No changes

DRAWING 015 - "CONSTRUCTION PROGRESS CHART"

No changes

DRAFT OF REPORT

Page 3 - Add statement that headroom under beams will be 10 ft.

Page 7 - Transmission will be to the United States system rather than the American system.

Page 13 - Delete the gate repair room.

Page 17 - Add statement that trash rack structural guides will be painted with an antifouling paint.

Page 41 - Add the following points to the supervisory control board:

1 - Synchronizing (to be used after partial start)

2 - Gate position indication

3 - Gate limit indication

4 - Speed adjustment indication

Page 47 - The intended connections to ground from the lightning arresters and the transformer neutrals are to be described more fully.

Copper is to be used instead of aluminum in the main ground bus.

Page 53 - Add a statement that each salt water heat exchanger system will be provided with a vacuum pump.

Page 64 - Add a statement that a portable pump will be provided to pump lubricating oil from the units to the dirty oil tanks. Delete statement that compressed air will be provided for derrick or hoist control and gate trash removal. Increase size of air receiver for 100 psi compressed air system from 100 cu ft to 200 cu ft.

Page 65 - Increase size of air receiver for 300 psi compressed air system from 11 to 30 cu ft.

Add statement that compressed air headers will be sectionalized.

## COST ESTIMATE

The cost estimate has been prepared on the basis of the contractor purchasing all materials and equipment, except the turbines and generators which would be purchased by the Corps of Engineers. With the thought that the Corps may wish to purchase other items as well: cranes, transformers, switchgear, etc., it was arranged for Messrs. B. L. Jeter and W. O. Wilcox to obtain the detailed back-up data on those items of equipment the Corps may possibly wish to purchase separately.

## APPENDIX

The table attached to Appendix V shows a different cost figure for the powerhouse gantry cranes than is shown in the detailed estimate. To assist some future reviewer, it was agreed that a footnote be added to the table explaining the reason for the difference in figures.